The association between "leg length to height ratio" and blood pressure in peri-adolescents

by

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Abstract

Background: Hypertension has a high prevalence in adults, and is a risk factor for cardiovascular diseases (CVD). Children and adolescents with higher levels of blood pressure tend to have high blood pressures as adults. Identifying children with higher levels of blood pressure would be critical for effectively implementing preventive measures among them. Stature components have been found to be associated with the risk of CVD in adults and some CVD risk factors in children. A few studies have found an association between leg length to height ratio (LLHR) and blood pressure in children; however, none of these studies have been in Canada.

Objective: To ascertain the relationship between leg length to height ratio and blood pressure in Canadian youth.

Methods: This cross- sectional analysis was done using data from the Heart Behavioural Environment Assessment Team (HBEAT) study, which was conducted with students from Niagara Catholic District School Board. Blood pressure and stature components of 689 students between the ages of 9-14 years were included for the analysis. The height range was 106.3 cm to 178.5 cm, and the blood pressure range was 67 mmHg to 142 mmHg for systolic blood pressure, and 30 mmHg to 96 mmHg for diastolic blood pressure. Regression models were used to examine relationships between LLHR and blood pressures.

Results: In the regression analyses, for every one standard deviation increment in LLHR, the systolic, diastolic, pulse pressure, and mean arterial pressure were on average 1.08 mmHg ($p<0.01$), 0.88mmHg ($p<0.01$), 0.20mmHg and 0.95mmHg ($p<0.01$) lower after adjusting for selected covariates.

Conclusion: Inverse relationships between LLHR and systolic, diastolic, and mean arterial pressure have been observed among Canadian youth. However, whether this can be used to predict the future risk of high blood pressure among children with a lower LLHR needs further studies.

Key words: hypertension, leg length to height ratio, adolescents

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List of Abbreviations

ABPM	Ambulatory blood pressure monitoring
APHV	Age at peak height velocity
BMI	Body mass index
BP	Blood pressure
CHD	Coronary heart disease
CVD	Cardiovascular disease
DBP	Diastolic blood pressure
HBEAT	Heart Behavioural Environment Assessment Team
HOMR-IR	Homeostasis model assessment of insulin resistance
LLHR	Leg Length to Height Ratio
LLHRSD	Leg Length to Height Ratio Standard Deviation
MAP	Mean Arterial Pressure
METs	Metabolic Equivalents
NCDSB	Niagara Catholic District School Board
NHANES	National Health and Nutrition Examination Survey
NHBPEP	National High Blood Pressure Education Program
OR	Odds ratio
PP	Pulse Pressure
SBP	Systolic blood pressure
SD	Standard Deviation
WC	Waist Circumference

Preamble

Cardiovascular disease (CVD) is a leading cause of morbidity and mortality throughout the world (World Health Organization(WHO), 2010; Yach, Hawkes, Gould & Hofman, 2004). Persistently elevated blood pressure, also known as hypertension, is one of the strong, independent risk factors for CVD (Stokes, Kannel, Wolf, D'Agostino, & Cupples, 1989). The prevalence of hypertension is high among adults; WHO (2013) reported that in 2008 the prevalence of hypertension was 40% among adults over the age of 25 years worldwide. In Canada, the prevalence of hypertension was 23.0% among adults in 2007/08 (Robitaille et al., 2012). Hypertension is a major public health concern due to its serious complications such as coronary heart disease (CHD), cardiac failure, kidney disease and stroke (Franklin, Khan, Wong, Larson, & Levy, 1999; Lawes, Vander, & Rodgers, 2008; Vasan et al., 2001). Worldwide, in 2008, 7.5 million deaths (12.8% of total deaths) were attributed to hypertension (WHO, 2009). More recently, WHO reported that hypertension accounted for 51% of deaths from stroke and 45% deaths from CHD (WHO, 2012).

Interestingly, stature components in adults, such as overall height, leg length, sitting height, and sitting height to leg length ratio, have been found to be associated with blood pressure levels (Gunnell et al., 2003; Lundberg, Diderichson, & Hallqvist, 2002; Schooling et al., 2007; Silventoinen, Baker, Thorkild, & Sorensen, 2012). Most of these studies showed that height and leg length were negatively associated with systolic blood pressure (SBP) and pulse pressure (PP) (Gunnell et al., 2003; Schooling et al., 2007). However, one study showed a positive association between height and diastolic blood pressure (DBP) which was seen among women only (Regidor, Banegas, Gutierrez-Fisac, Dominguez, & Rodriguez-Artalejo, 2006). In addition, one study found that leg to trunk ratio was negatively associated with SBP and DBP (Gunnell et al., 2003). The association between stature components and blood pressure may reflect the impact of early life environment on the development of hypertension since short leg length is considered a proxy of poor nutritional status (Bogin, Smith, Orden, Varela Silva, & Loucky, 2002; Padez,Varela Silva, & Bogin, 2009).

Evidence suggests that childhood blood pressure is a predictor of adult blood pressure, as shown by tracking blood pressure from childhood to adulthood (Bao, Threefoot, Srinivasan, & Berenson, 1995; Klumbiene, Sileikiene, Milasauskiene, Zaborskis, & Shatchkute, 2000; Rosner, Hennekens, Kass, & Miall, 1977**).** Identifying children and adolescents who are at risk of developing higher blood pressure levels in adulthood may help to effectively initiate appropriate pro-active interventions to reduce the burden of hypertension when these children become adults.

In children, hypertension is defined as having a blood pressure that is greater than the 95th percentile for age, sex, and height percentile. To diagnose hypertension, high blood pressure levels should be present on more than three occasions. As well, pre-hypertension is defined as having a blood pressure between the 90th and 95th percentile for age, gender, and height percentile of the child (Sinaik,1996).

The prevalence of hypertension and pre-hypertension among children in Canada appears to be very low (< 1% and 2.1%, respectively), according to the data from the Canadian Health Measures Survey 2007-2009 (Paradis, Tremblay, Janssen, Chiolero, & Bushnik, 2010; Shi, de Groh, & Morrison, 2012). Nevertheless, higher prevalence rates were observed among Canadian rural children and adolescents aged 4-17 years with 7.4% having hypertension and 7.6% having pre-hypertension (Salvadori et al., 2008).

The guidelines to detect hypertension and pre-hypertension are established in the report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents by The National High Blood Pressure Education Program Working Group (NHBPEP) (Falkner & Daniels, 2004). It is recommended that blood pressure be measured in children and adolescents at each health care visit after 3 years of age. As well, high blood pressure levels should be present on more than three occasions to make the diagnosis (Falkner & Daniels, 2004). Hence, diagnosis has become a difficult task in the clinical setting for several reasons, including blood pressure variability, white coat hypertension, and un-cooperative children (Hansen, Gunn, & Kaelber, 2007). Also, with such a low prevalence based on the Canadian Health Measures Survey results, by measuring blood pressure, there would not be much benefit with respect to identifying the patients in pediatric age range.

The risk association between stature components and CVD in adulthood has suggested that early life nutrition status may affect the development of the disease in later life. Previous research showed an inverse relationship between LLHR and blood pressure (Harding et al., 2010; Rao & Apte, 2009; Rao & Kanade, 2007; Liu et al., 2014). Interestingly, LLHR among children has been linked to overweight/obesity (Liu, Akseer, Faught, Cairney, & Hay, 2012), to blood pressure in two samples of boys and girls from India (Rao & Apte, 2009; Rao & Kanade, 2007), and to metabolic syndrome in children in China (Liu et al., 2014). Since Canada is experiencing an increasing prevalence of hypertension in adults (Robitaille et al., 2012), it is important to find the reasons why and how the low prevalence in childhood becomes a considerably higher prevalence of hypertension among adults. Sedentary life style, poor dietary habits, genetic effect, and other contributing co-morbidities can be some of the factors promoting the development of hypertension. As well, LLHR, a possible indicator of early life environmental exposures, may also be linked to blood pressure. However, no study has been done among Canadian children and adolescents that looks at the relationship between to blood pressure and LLHR. It would be interesting to see such a relationship can be observed among Canadian children.

The objective of this present study is to examine the relationship between LLHR, and blood pressure among children and adolescents in a sample of Canadian children. It is hypothesized that LLHR, as a proxy of early life nutritional status, is negatively associated with blood pressure levels.

Chapter One: Literature Review

Hypertension is a major public health concern due to its links to heart disease, stroke, kidney disease, and premature death (Benetose, Safar, Rudnichi, & Smulyan, 1997; Collins et al., 1990). Considering the significant medical and financial burden associated with hypertension, it is important to identify the target groups who are more likely to develop hypertension. This is especially important among youth as childhood blood pressure is linked to blood pressure in adults (Bao, et al., 1995).

In this review, first the burden of hypertension is described. To better understand the impact, the components of blood pressure are explained and hypertension and pre-hypertension are defined using the current criteria, particularly criteria that have been used in children and adolescents. Next, the theory behind this thesis linking LLHR with adult blood pressure is examined along with the existing evidence. Then the stature components and their relationship with blood pressure in adults and children are reviewed, examining a potential association between LLHR and blood pressure among children and adolescents. Lastly, a summary is provided, in which gaps in the literature are identified.

Health Impact of Hypertension and Pre-hypertension

Hypertension is an independent risk factor for CVD (Benetose et al., 1997; Collins et al., 1990; Howell, Sear & Foe, 2004; Stokes et al., 1989). Hypertension can lead to serious consequences such as CHD, heart failure, kidney disease, visual impairment, and stroke (Vasan et al., 2001; Lawes et al., 2008).

Prevalence of hypertension and pre-hypertension. The current prevalence rate of adult hypertension in Canada has been shown to be between 17.0%-24.4% (Robitaille et al., 2012; Tu, Chen, & Lipscombe, 2008; Statistics Canada, 2013; Wilkins et al., 2010). There has been an increase in age standardized prevalence from 12.5% in1998/1999 to 19.6% in 2007/2008 (Robitaille et al., 2012). This was a 56.8% increase for an 8- year period. Global prevalence of hypertension among adults aged over 25 years was 40% in 2008 (WHO, 2013).

The incidence and prevalence in Canada have shown considerable differences in different regions and among the two sexes. The age standardized incidence and prevalence of hypertension in Atlantic region were 3.3% and 23.3% while they were 2.5% and 19.0% in the territories and Western Canada combined. Also, both sexes showed similar prevalence up to 60 years but after 60 years, females showed a higher prevalence (Robitaille et al., 2012).

The prevalence of hypertension in children is reported to be low in most studies. In Canada, reported prevalence rates vary between < 1% and 7.4% (Paradis et al., 2010; Salvedori et al., 2008; Shi et al., 2012). Regarding data from the Canadian Health Measures survey (2007-2009), Shi et al., 2012 and Paradis et al., 2010 reported the prevalence of hypertension and pre-hypertension as 0.8% and 2.1 %, respectively, in a nationally representative sample of children and adolescents. Salvedori et al., (2008) conducted a study among Canadian children and adolescents from a rural community and found a higher prevalence. The prevalence of hypertension and pre-hypertension was 7.4% and 7.6%, respectively. However, a study done in Quebec, Canada using the Quebec Children and Adolescent Health and Social Survey (QCAHS) data, showed high prevalence rates (Paradis et al., (2004). Analysis was done at ages 9, 13, and 16 years in girls and boys separately. Pre-hypertension prevalence varied from 6%, 7% and 7% in the three age groups respectively, and hypertension prevalence varied from 7%, 13% and 17% in the different age categories considering systolic blood pressure cut-offs.

Table l

The Prevalence of Blood Pressure in Children and Adolescents and Method of Measurements

Study	Participants	BP apparatus	Resting (min)	Measures	Interval (min)	Calculation (Average)	HT (%)	Pre-HT (%)
Shi, Groh & Morrison (2012)	Canadian 6-17 yrs	BpTRU™ device	5	6	1	5	<1	2.2
Salvadori et al., 2008	Canadian, rural 4-17 yrs			3		3	7.4	7.6
Paradis et al., 2004	Canadian, Qubec 9, 13, 16 yrs	Oscillometric (Dinamap XL, model CR9340, Critikon Co)	5	3	1	2&3	SBP 9- 7 13- 13 16- 17 DBP	 6 7 7
Hansen, Gunn & Kaelber, 2007	USA, Ohio 3-18 years	Automatic					<1%	3.6
King, Meadows, Engelke, & Swanson, 2006	USA, Rural, 6-19 years	Sphygmomanometer	5	2	2	1&2	21.6	

Pre HT: Prevalence of Pre-hypertension

HT: Prevalence of hypertension

In the United States of America (USA), between 1999 and 2006, 3.4% of children aged 3 to 18 years experienced hypertension. National surveys conducted in the USA reported that the prevalence of pre-hypertension and hypertension increased by 2.3% and 1% from 1988 to 1999, respectively (Din-Dzietham, Liu, Bielo, &Shamsa, 2007). Inconsistencies in the number of repeated measurements, method of BP measurement and calculation, and having a rest period before measuring blood pressure can be identified as reasons for the reported variability in prevalence rates. Table 1 summarizes blood pressure prevalence in children and adolescents and the method of taking blood pressure measurements.

As seen in Table 1, blood pressure can vary depending on the age range of participants, study population, measurement methods used, and number of measurements of blood pressure. These differences may impact the reported prevalence of hypertension. When several measurements are taken, blood pressure can reduce gradually, especially with white coat hypertension.

White coat hypertension is when a participant or a patient has high blood pressure readings at the clinical setting (office) or in front of a doctor, while having a lower blood pressure measurement at home or away from the clinic. More specifically, it is defined as when blood pressure is more than 140/90 mmHg at the office on more than three occasions and less than 140/90 mmHg at home (Franklin et al., 2013). Due to white coat hypertension, blood pressure tends to be high on the first measurement and reduces gradually with serial measurements. White coat hypertension has been addressed in the 2016 Canadian Hypertension Education Program Guidelines (Leung et al., 2016). Shi et al., (2012) highlights that the very low prevalence of hypertension could be due to the serial measurement of blood pressure. Therefore, it is evident that standardization of blood pressure measurement is vital in order to obtain accurate prevalence rates, as well as compare prevalence rates.

Recommendations for proper blood pressure monitoring are given in The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents by the National High Blood Pressure Education Program (2004) in the United States. As the blood pressure tables are prepared using the auscultatory method, it is recommended to use a standard clinical sphygmomanometer with an appropriate size cuff and a stethoscope. It emphasizes the importance of the child needing to sit quietly for 5 minutes with his/her back supported and feet flat on the floor. The right arm is preferable, and the cubital fossa should be at heart level. The stethoscope is placed over the cubital fossa and Korotkoff sounds are used to measure systolic (SBP) and diastolic blood pressure (DBP).

Economic burden of hypertension and pre-hypertension. The economic burden of hypertension in the USA considering annual direct and indirect costs of hypertension was estimated at approximately $69.9 billion, and $23.6 billion, respectively, between 2005 and 2008 (Yoon, Gillespie, George, & Wall, 2012). Similarly, in 1998, $108.8 billion was attributed to the cost of hypertension in the United States of America (Hodgson & Cai, 2001). This accounted for 12.6% of the national spending for health in 1998. According to the Public Health agency of Canada (2013), the cost for CVD was 15% of the total health expenditure in 2000. There was no published data for the amount spent only on hypertension in Canada.

Basic concepts of blood pressure. To better understand the impact of hypertension, it is important to know the basic concepts of blood pressure, diagnosis of hypertension and pre-hypertension, and some key factors that determine blood pressure. However, definitions of hypertension differ in adults from that in children and adolescents.

There are four components of blood pressure that can be identified: SBP, DBP, pulse pressure (PP), and mean arterial pressure (MAP) (Franklin et al., 2009). SBP is the maximum pressure at the peak of the contracting phase in the cardiac cycle (when the ventricles of the heart contract). DBP is the minimum pressure at the dilating phase of the cardiac cycle (when the ventricles of the heart relax) (Pal & Pal, 2006). PP corresponds to the pulsatile component of blood pressure; it is the difference between SBP and DBP and is considered an independent risk predictor of CVD (Srandberg & Pitkala, 2003; White, 2002). MAP, calculated as DBP +1/3(PP), corresponds to the steady component of blood pressure which represents left ventricular contractility, heart rate, and vascular resistance and elasticity (Sesso et al., 2000).

There are two types of hypertension with respect to cause: primary (essential) hypertension and secondary hypertension. Primary hypertension is not directly related to an identified cause/disease, while secondary hypertension is a consequence of an identified disease, such as kidney disease (Carretero & Oparil, 2000; Prisant , Mawulawde,Kapoor, & Joe,2004), endocrine diseases and coarctation of aorta (Hansen et al.,, 2007). In this literature review, I focus mainly on the factors related to primary hypertension.

Diagnosis of hypertension and pre-hypertension.

Adults. The 2016 Canadian Hypertension Education Program for adults clearly states how to diagnose hypertension in a stepwise manner (Leung et al., 2016). Blood pressure readings should be taken using a validated device, applying the correct method by health care professionals trained to take blood pressure. Automated blood pressure device is preferred as the method of office blood pressure measurement. When using an automated device, a SBP that is more than, or equal to 135, and/or DBP is more than, or equal to 85 mmHg is considered high. When a non- automated device is used 140/90 mmHg is considered high. Except for hypertensive urgencies and emergencies, two additional readings should be taken in the same initial visit. For non- automated devices, the first reading should be discarded and the other two readings averaged. For automated BP device, the recorded averaged measurement by machine should be taken. If SBP is more then or equal to 180 mmHg and/or DBP is more than or equal to 110mmHg, then hypertension is diagnosed. To detect target organ damage and to identify other cardiovascular risks, the person is evaluated through their medical history, physical examination, and laboratory testing. A second visit is to be scheduled within a month (Leung et al., 2016).

Hypertension is diagnosed with office BP measurement depending on the clinic visit. At the second visit, hypertension is diagnosed in people with target organ damage, diabetes, or kidney disease, and if SBP is more than or equal to 140, and/or DBP is more than or equal to 90 mmHg. If out of office blood pressure measurements are not available, office blood pressure monitoring (OBPM) is used to diagnose hypertension, in subsequent visits. Hypertension is diagnosed if the average blood pressure from the first three visits is more than 160/100 mmHg or if the average blood pressure from the first five visits is more than 140/90 mmHg.

Pre-hypertension among adults is defined as: 130 ≤ SBP ≤139 mmHg and/or 85≤ DBP ≤89 mmHg. For these individuals, an annual physical examination is recommended because they are at risk of developing hypertension (Leung et al., 2016; Qureshi, Suri, Kirmani, Divani, & Mohammad, 2005). ABPM and HBPM are not used in the current research and, therefore, not discussed here.

Children and adolescents. Diagnosing hypertension in children and adolescents is different from adults. The Fourth report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (National High Blood Pressure Education Program, 2004) outlines the criteria by which to diagnose hypertension in children and adolescents from ages 1-19 years. Hypertension is diagnosed when average SBP and/or DBP is equal to or greater than the 95th percentile of blood pressure according to the age, sex and height percentile. Pre-hypertension is identified when SBP or DBP is between the 90th and 95th percentile depending on The USA reference data from the Fourth Report were used in the Canadian Health Measures survey to identify the prevalence of hypertension and pre-hypertension depending on age, sex, and height percentiles (Paradis et al., 2004; Shi et al., 2012). The following section provides a brief review of the determinants of blood pressure in children. age, sex, and height percentile (Table 2).

Table 2

Blood Pressure Status Depending on the Blood Pressure Percentiles in Children and Adolescents, according to The Fourth report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents (National High Blood Pressure Education Program, 2004).

Blood pressure cut-offs	Blood pressure status
<90th percentile	Normal
>= 90-<95th percentile	Pre-hypertension
>=95 th percentile or >120/80 mmHg	Hypertension

Key factors determining blood pressure in children. Age is a major determinant of blood pressure; both SBP and DBP increase with age regardless of sex (Landazuri, Granobles & Loango, 2008; Sánchez, Labarthe, Forthofer, & Fernández-Cruz, 1992; Shea et al., 1994). A meta-analysis, using pooled data from worldwide literature on children aged 6-18 years, examined the effect of age on blood pressure (Brotons, Singh, Nishio, & Labarthe, 1989). The analysis found a steady increase in SBP of 1.4mmHg per year on average from 6 to12 years in boys, and from 6 to 9 years in girls. In boys, SBP increased at a rate of 3.2 mmHg per year on average from 12 to 15 years, and at 18 years, the rate of increase was 0. In girls, the increase of SBP was 2.1 mmHg per year on average from 9 to 13 years, and SBP started to decline at the age of 16. Similar results were seen in Sánchez et al., 1992.

Difference in blood pressure by sex among children has been highlighted by Manatunga, Jones, and Pratt, (1993). In this longitudinal study, children had a mean age of around 8 years at entry, and blood pressure was monitored every 6 months for 2 to 5.5 years. The results revealed that SBP was higher in boys than girls (p=0.0048), with no sex difference in DBP.

Physiological maturation is another determinant of blood pressure among children, and height is considered the best indicator of physiological maturation as it is related to blood pressure independent of chronological age (Gillum, Prineas, & Horibe, 1982). More so, height percentile would be a better indicator. Blood pressure in children is positively correlated to height (Adams-Campbell et al., 1992; Rona, Qureshi, & Chinn, 1996). According to the United States Department of Health and Human Services (National High Blood Pressure Education Program, 2004), when diagnosing hypertension in children and adolescents, physicians need to take height into account.

Physical activity plays a key role in the determination of blood pressure. It has been observed that a higher level of physical activity is related to low blood pressure. Leary et al., (2008) found that there was a reduction in SBP and DBP in physically active, 11-12-year old children in a population based study in the United Kingdom. By reviewing the up-to-date literature, Torrance, McGuire, Lewanczuk, & McGavock (2007) explained that 40 minutes of moderate to vigorous exercise would reduce blood pressure in obese children.

Nutrition is another determinant of blood pressure. Reducing salt content, increasing potassium intake by adding fruits and vegetables to the diet, reducing fat content by minimizing dairy products, and replacing meat with fish have been identified as important modifications to the diet in order to have a normal blood pressure (MacGregor, 1999). A recommended diet has been introduced by the USA which is called the Dietary Approaches to Stop Hypertension. This diet acts to reduce salt, total and saturated fat, as well as increase potassium and magnesium, by reducing salty food, meat and dairy products, and increasing fruits, vegetables and nuts (Geleijnse & Grobbee, 2003; Sacks et al., 1999).

As defined earlier, the burden of hypertension on the person and on society is substantial. As such, prevention, early detection, and treatment become essential in the management of an individual’s health. One challenge is that hypertension can be asymptomatic and complications may arise without any obvious awareness by the person (Kessler & Joudeh, 2010). The asymptomatic nature of hypertension makes it more difficult to diagnose. One possible method for early detection is to identify the children (at-risk group) those who have a tendency to develop hypertension as adults. Tracking of blood pressure becomes an essential methodology in terms of discovery and diagnosis of high risk individuals. The next section will discuss how the literature examines the tracking of blood pressure levels among children in relation to future blood pressure levels as adults.

Tracking Blood Pressure from Childhood to Adulthood

Numerous studies have shown that childhood blood pressure is predictive of blood pressure in adulthood (Bao et al., 1995; Chen & Wang, 2008; Klumbiene et al., 2000). For example, the results from a longitudinal study of 505 adolescents aged 12-13 years old at baseline, who were followed to 20 years of age, indicated that childhood blood pressure was one of the strongest predictors of adult blood pressure (Klumbiene et al., 2000). Their results indicated a significant correlation between adult blood pressure and childhood blood pressure. For SBP, the correlation coefficients were 0.40 and 0.24 for males and females, respectively. Similarly, for DBP the correlations were 0.14 and 0.34 for males and females, respectively. Bao et al., (1995) showed similar results. They initially examined children 5 to 14 years old and then examined them 15 years later; about 40% of youths who were in the highest quintile for both SBP and DBP at the initial assessment were in the top quintile after 15 years. These children were not necessarily diagnosed as hypertensives or pre-hypertensives but made up the majority of adults subsequently diagnosed with hypertension (Bao et al., 1995).

Consistent with this child-adult link in blood pressure, children with pre-hypertension are at increased risk of developing hypertension (Qureshi et al., 2005). The results from the National Childhood Blood Pressure database indicated that among 8,533 boys and girls aged 13-15 years with blood pressure measurements at baseline, 14% of boys and 12% girls who were in the pre-hypertension group were diagnosed with hypertension after a 2-year follow-up (Falkner, Gidding, Portman, & Rosner, 2008).

Blood pressure tracking can be used to identify the at- risk children who have the potential to have high blood pressure when they become adults. The guidelines regarding blood pressure measurement is provided by The Fourth Report from the National High Blood Pressure Education Program Working Group on Children and Adolescents (2004). These guidelines suggest taking at least one blood pressure measurement at each health episode in children more than 3 years old when they are seen at a medical care setting. For children, less than 3 years old, blood pressure measurements would be considered in special circumstances only (Appendix A).

Blood pressure monitoring in children at clinic visits can be a difficult task for several reasons (Hansen et al., 2007; Smith, 2005). It is also reported that hypertension in children and adolescents is underdiagnosed (Hansen, Gunn and Kielber, 2007). Blood pressure variability is one limitation as blood pressure can have short-term and long-term fluctuations. Short-term fluctuations include beat to beat, minute to minute, hour to hour, and day and night changes. Long-term fluctuations involve changes in days, weeks, months, seasons, and years. Variability can be due to the external environment, behavioural factors, and intrinsic cardiovascular regulatory mechanisms (Parati, Ochoa, Lombardi & Bilo, 2010). Other reasons include white coat hypertension (De la Sierra, 2013), uncooperative children, difficulty in taking repeated measurements, unavailability of correct cuff sizes, unavailability of height percentile and blood pressure percentile charts to diagnose hypertension, and time constraints. These practical difficulties may be relevant to anthropometric measurements, but it is likely to be more marked with blood pressure measurement.

Considering these challenges, searching for another measure is essential to identify individuals with hypertension or, at minimum, the high-risk group who have a greater likelihood of developing hypertension. Body measurements are known to have links to CVD in adults and children and may provide an avenue by which to recognize an alternate comparative measure that will relate to blood pressure in children and adolescents. To accomplish this, it is necessary to examine the association of body measurements to CVD and, more specifically, to blood pressure.

Stature Components and their Association with Cardiovascular Risk

While leg length is commonly seen as being associated with CVD, a number of studies have also examined the relationship between various stature components and cardiovascular risk.

Stature components and CVD in adults. Stature components have been found to be associated with cardiovascular risk factors, CHD, and mortality (Han, Hooper, Morrison, & Lean, 1997; Lundberg et al., 2002; Gunnell, Smith, Frankel, & Nanchahal, 1998). For example, in a cross-sectional study, adult height was inversely related to the odds of myocardial infarction in both men and women. The odds ratio of myocardial infarction among those in the shortest quartile of height was approximately two times higher compared to those in the tallest quartile (Lundberg et al., 2002). In a longitudinal cohort study, shorter childhood leg length has also been found to be significantly related to higher CHD mortality among adult men and women (Gunnell et al., 1998). In the same study, childhood leg length was more strongly linked than overall height to CHD mortality. These findings highlight that being tall and having a longer leg length are protective against developing CVD. It further suggests that childhood short leg length is considered as a proxy indicator of adverse diet and other environmental factors in the first few years of life, and is associated with adult CHD mortality (Gunnell et al., 1998).

Stature components have also been found to predict other CVD risk factors, especially obesity and diabetes (Asao, Baptiste-Roberts, Erlinger, & Brancati, 2006; Pliakas & McCarthy, 2009). Asao, Baptiste-Roberts, Erlinger, & Brancati., 2006 examined stature components like height, leg length, and LLHR and their relationships with adiposity, insulin intolerance, and glucose intolerance, in a cross-sectional analysis. LLHR was used to examine the risk of diabetes among adults aged 40-74 years, using the 1988-1994 National Health and Nutritional Survey (NHANES ш) in the USA. They showed that especially in women lower height, lower leg length, and lower LLHR was associated with higher percent body fat. Also, lower height, leg length, and LLHR were shown to be associated with prevalence of diabetes adjusted for age. With one standard deviation (SD) drop in LLHR, there was a 5% increase in mean HOMR-IR (homeostasis model assessment of insulin resistance, a measure of insulin resistance) (β-coefficient from linear regression model for the log-transformed HOMA-IR = 1.05), and a 19% increase in prevalence of diabetes (prevalence ratio=1.19). In comparison, the increase in diabetes prevalence with each SD decrease in leg length and LLHR were 1.17 (0.98-1.39), and 1.19 (1.02-1.39), respectively.

Likewise, previous studies (Gunnell et al., 2003; Langenberg, Hardy, Breeze, Kuh, & Wadsworth, 2005; Regidor et al., 2006; Schooling et al., 2007) have observed inverse relationships between adult stature components and blood pressure levels. These stature components included standing height, sitting height, and leg length. Negative associations were seen between leg length and blood pressure (Langenberg et al., 2005), as well as leg length to trunk ratio and blood pressure (Gunnell et al., 2003).

The results from a study in Scotland of men and women aged 30-59 years showed that for every one SD increase in leg length, SBP was 1.14 mmHg (p=0.02) lower in men and 1.09 mmHg (p=0.01) lower in women after adjusting for age (Gunnell et al., 2003). A similar negative relationship between both SBP and DBP and leg length to trunk ratio was observed among both men and women (Gunnell et al., 2003).

Evidence from a longitudinal study supported the finding that shorter height and shorter leg length were associated with higher blood pressure in both sexes (Langenberg et al., 2005). Using the national birth cohort of 1946 in Britain, researchers examined the stature and blood pressure associations at different ages, specifically at 36, 43, and 53 years of age. At 53 years, each centimetre increase in leg length resulted in a lower PP, SBP, and DBP by 0.36 mmHg, 0.48 mmHg and0.12 mmHg respectively, and provided evidence as to the effect of poor growth in early life on the arterial tree (Langenberg et al., 2005). SBP and PP showed similar associations with leg length in research by Schooling et al., (2007) who examined more than 10,000 Chinese adults aged 50 years and older (3,021 men and 7,283 women). The findings showed that with each additional centimetre in leg length, there was a reduction of SBP by 0.58 mmHg (95 % CI -1.00 to -0.16). Similarly, PP decreased by 0.67 mmHg for every one centimetre increase in leg length (95% CI -0.96 to -0.38). However, some limitations, such as incorrect height measurements, due to the effects of osteoporosis, were seen when using an older population for this study (Schooling et al., 2007).

Silventoinen et al., (2012) evaluated the longitudinal relationship between child height and subsequent adult risk of CHD. The study was conducted in the municipality of Copenhagen with children born between 1936 and 1976 and was comprised of 232,063 children. In this study, the height measurements were taken annually between 7 to 13 years of age, and fatal and nonfatal CHD events were collected through registries. Results showed an inverse relationship between child height z- scores and the risk of CHD in adults as indicated by hazard ratios (HR). The association was strongest at 7 years of age among both boys and girls (HR = 0.91, CI 0.90–0.92 in boys and HR=0.88, CI 0.86–0.90 in girls). The strength of the association decreased gradually with age, but was still significant at 13 years of age (HR = 0.95, CI 0.94–0.97) in boys and (HR= 0.91, CI 0.89–0.93) in girls. Table 3 is a summary of body measurements with their link to blood pressure and other CVD risk.

Table 3

A Summary of the Utility of Body Measurements and Their Link with CVD and Blood Pressure

Body Measure	Study	Results
Height	Langenberg et al., 2005	Short height was associated with high PP & SBP, but not DBP
	Redigor et al., 2006	Height showed an inverse relationship with SBP and a direct relationship with DBP; Short stature was independently associated with increased PP.
	Gunnell et al., 2003	Height had an inverse relationship with SBP & DBP (not significant
Leg Length	Langenberg et al., 2005	Increase of leg length by 1 cm reduces SBP by 0.021 mmHg and PP by 0.020 per year. Effects stronger with age. DBP showed similar effects but less evident with age.
	Gunnell et al., 2003	Longer leg length associated with reduced SBP and DBP.
	Asao et al., 2006	1 SD lower leg length showed a relative prevalence of T2DM of 1.17(0.98-1.39).

Trunk Length	Langenberg et al., 2005	Did not show any association with BP measurements
	Gunnell et al., 2003	No association
Leg length to trunk ratio	Gunnell et al., 2003	High leg length to trunk ratio showed lower BP (SBP, DBP)
Sitting height to leg ratio	Schooling et al., 2007	No significant association with blood pressure
LLHR	Asao et al., 2006	1 SD lower LLHR showed a relative Prevalence (Prevalence rate ratio) of T2DM of 1.19(1.02-1.39).
	Rao & Apte, 2009	Lower LLHR was associated with high SBP (OR=1.69); also with high DBP(OR=1.99)
	Rao & Kanade, 2007	Lower LLHR was associated with high SBP(OR=2.28) and high DBP (OR=2.27)

T2DM: Type 2 diabetes mellitus

OR: Odds ratio

Stature components and CVD risk factors in children. Unlike studies in adults, only a few studies have been conducted on the relationship between children's stature components and CVD risk factors. Previous studies have used height, leg length, and LLHR in the prediction of CVD risk.

A longitudinal study was conducted in London, England of approximately 4,800 school children (11-13 years at the baseline), who were followed for 3 years (Harding et al., 2010). The results showed that leg length and height at 11-13 years of age were independent predictors of blood pressure 3years later when they were adolescents. While overall height showed a positive association with blood pressure, leg length showed a negative association with SBP and DBP among adolescents in both sexes (Harding et al., 2010). The association of leg length and blood pressure was similar to the results observed among adults, suggesting it could be a valuable predictor of blood pressure in adolescents.

Among children, it may be more meaningful to use a relative measure of leg length and stature, such as LLHR, than leg length alone since their body measurements change rapidly as a result of growth during this period. A study conducted among adolescent boys aged 9-16 years from two schools in India found that the adolescent boys who had a lower LLHR had higher blood pressure; however, its risk association with higher SBP or DBP was dependent on social economic status (Rao & Apte, 2009). This may have represented nutritional status of the children and adolescents. Individuals were categorized according to the socioeconomic status (i.e., lower and higher socioeconomic classes). Odds ratios were calculated for high SBP and high DBP for the lowest tertile of LLHR compared to highest tertile. More specifically, among adolescents in the lower socioeconomic class, those in the lowest tertile of LLHR compared to the highest tertile had a 99% higher odds of having high DBP (OR: 1.99, 95% CI: 1.14, 3.47, $p < 0.05$). Similarly, among adolescents in the higher socioeconomic class, those in the lowest tertile of LLHR had 69% higher odds of having high SBP (OR: 1.69, 95% CI: 1.02, 2.77, $p < 0.05$) compared to those in the highest LLHR tertile. Similar results were seen among adolescent girls (Rao and Kanade, 2007). Compared to the highest LLHR tertile, those in the lowest tertile of LLHR had higher SBP and DBP levels. As well, in the lower socioeconomic class, compared to the highest tertile, the odds ratio for high DBP in the lowest tertile was 2.28 ($p<0.001$). Similarly, in the higher socioeconomic class, compared to the highest tertile, the odds ratio for high SBP in the lowest tertile of LLHR was 2.27 ($p< 0.01$). The results of Rao and Kanade (2007), who examined girls, also indicated that leg length to sitting height ratio blood pressure showed similar results.

A longitudinal study conducted in Southern Ontario, Canada among school children in grade 5, used LLHR to predict overweight and obesity status (Liu et al., 2012). It showed that the LLHR measured at grade 5 was negatively associated with the risk of overweight and obesity when the children were in grade 8. Compared to the first quartile (Q1) of LLHR, the odd ratios (OR, 95% CI) of overweight/obesity in quartiles Q2-Q4 were 0.60 (0.29-1.21), 0.43 (0.21-0.89), and 0.32 (0.15-0.70), respectively, for boys. Similarly, for girls, the odds ratios were 0.77(0.36-1.64), 0.60 (0.28-1.29), and 0.27(0.12-0.62), respectively. These results suggest that LLHR can be used to predict the risk of future overweight/obesity.

Rao and Apte (2009) reported that LLHR was a good indicator of health risk such as blood pressure. The researchers suggest validating the use of LLHR to predict health risks in other populations. To the best of my knowledge, there is no study examining the association between LLHR and blood pressure among Canadian youth; therefore, investigation of this connection among children in Canada may provide another method of identifying potential high risk group for the development of hypertension.

Possible Mechanisms of Stature- Disease Association

The etiology of essential hypertension is not totally understood, but it is suspected that life experiences might be involved in its process. Early life environment theory (Leitch, 1951, 2001) suggests that early negative life conditions, such as poor nutritional status, illness, and disadvantaged psychosocial factors, might be associated with late life disease occurrence, while leg length can be used to assess these negative early life experiences. For example, analysing data from the 1937 Carnegie UK Dietary and Clinical Survey, Leitch (1951) demonstrated that early life exposures in terms of improved nutrition in infancy and childhood resulted in greater leg length. Leitch (1951) highlighted that leg length as measured by cristal length (height from floor to the highest point of iliac crest) was a better measurement to predict socioeconomic status (represented by average weekly expenditure on foods per person in family) than overall height. In addition, Leitch (1951, 2001) highlighted that the LLHR was an indicator of childhood development that reflected early life experiences and health. However, "early life" was not defined by Leitch, with respect to an age range.

Using the 1946 British National Cohort, Wadsworth, Hardy, Paul, Marshall, & Cole (2002) demonstrated that breast feeding and higher energy intake at 4 years of age was positively associated with greater leg length in adults; adult trunk length was negatively associated with childhood illnesses but not related to diet. It was highlighted that the fastest leg length growth occurred in early childhood. Wadsworth et al., examined the energy intake at 4 years referring to nutritional status and its relationship to leg length (growth). It can be argued that birth to 4 years or pre-school years can be considered as early life. Hence, these findings support the theory of Leitch (1951).

Investigating the relationship between body fat and relative leg length (leg length/stature or LLHR), Frisancho, 2007, examined the relative leg growth and sitting height growth from 2 to 20 years. He highlighted that leg length increased from 2 to about 12 years and plateaued. Leg growth was more rapid than trunk growth in children from 2 to 12 years (Figure 1). Increased variability in a person's height was explained more by leg length than trunk length. In other words, leg length contributes more to height than trunk length. Frisancho also showed the change of relative leg length over time. Between the ages 9 to 14 years, the change of LLHR was minimal; almost a plateau.

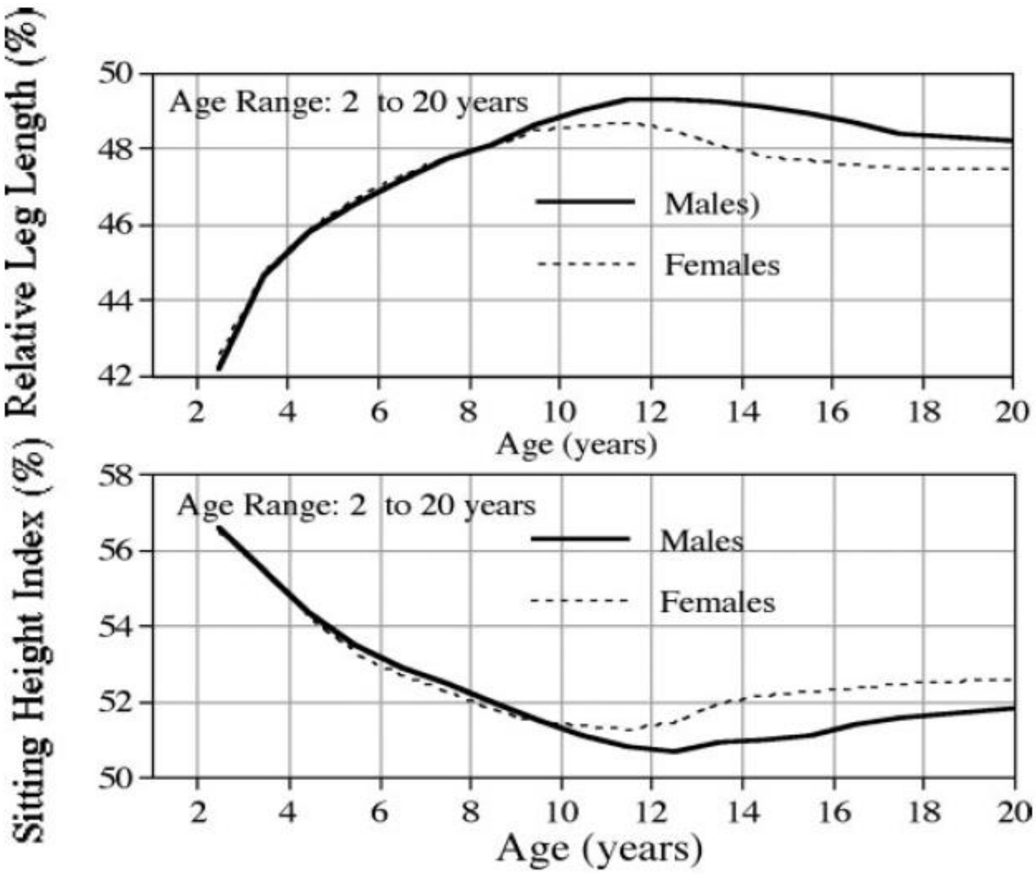

Figure 1. Relative leg length and sitting height (Frisancho, 2007)

Based on Leitch's (1951, 2001) observation, others have examined height, leg length, sitting height ratio (height of head, neck, and trunk to overall height as a percentage), and relative leg length as indicators of the quality of the environment during growth (Bogin et al., 2002; Padez et al., 2009). Bogin et al., 2002 compared body measurements in 5 to 12- year-old Maya children living in Guatemala (lower socioeconomic status), to Maya-American children who migrated to America (higher socioeconomic status). Compared to the Guatemalan children, Maya-American children were on average 11.54 cm taller and had 6.83 cm longer legs. Also, Maya-Americans had a shorter sitting height ratio indicating a longer leg length. In a similar study (Padez et al., 2009) that examined growth status among 9-17-year-old Mozambique adolescents, relative leg length was calculated by dividing the leg length by sitting height as a percentage. In the Mozambique sample, individuals from the centre of the city (socioeconomically higher) and individuals from slums (socioeconomically lower) were compared. The Mozambique sample was also compared with an African–American reference sample. Individuals were categorized into 9-11 years of age, 12-14 years of age, and more than 15 years of age. Subjects from the slums showed a higher percentage of stunting than those from the city (boys and girls, 6.1% and 3.7% vs 0.3% and 1.8%, respectively). Also, boys and girls of all age groups in the slums showed that they were significantly shorter than the African-American reference group.

Leitch's (1951, 2001) observation was used to analyse the body measurement-disease associations in several subsequent studies. In a longitudinal study using the British national birth cohort of 1946, the leg and trunk length at 43 years of age were evaluated with respect to childhood health, diet, and family circumstances (Wadsworth et al., 2002). This study concluded that leg and trunk had different growth rates at different developmental periods, and that leg length reflected socioeconomic circumstances and diet, while trunk length reflected illness and psychological disturbances. David Gunnell (2002), in his commentary on Wadsworth et al.'s work, explained that leg length and trunk length were potential anthropometric biomarkers for exposures underlying the` stature –disease associations. He also addressed that height during childhood was associated with prenatal growth, parental height, and child's health, nutrition, and stresses which were mainly pre-pubertal exposures. Gunnell (2002) further explained that postnatal growth is mainly due to the growth of the legs rather than the trunk, and that slowing of growth at this time could adversely affect the growth of the lower limbs more so than the trunk. He concluded that height could be used as a biomarker of postnatal exposures affecting growth throughout childhood, and that leg length could be considered as the marker of pre-pubertal growth reflecting early nutritional status.

Moreover, significant increases of secular trends in height suggest that nutritional improvements contributed to the increases in leg length relative to trunk length (Swami, Einon, & Furnham, 2006; Tanner, Hayashi, Preece, & Cameron, 1982). Tanner et al.,1982 showed this by conducting a study between 1957 and 1977 in Japanese children aged 5 to 17 to see the difference in height and its components. They showed no increase in sitting height from 1957 to 1977 but the increase in height was almost all due to the increase of leg length.

Comparing Use of LLHR with Other Stature components and Its Association to blood Pressure

Among the stature components, height, leg length and leg length to height ratio can be compared to identify the best measure to demonstrate an association with blood pressure. Several studies done in adults (Gunnell et al., 2003; Langenberg et al., 2005; Regidor et al., 2006), and few studies among children (Harding et al., 2010; Rao & Apte, 2009; Rao & Kanade, 2007) have shown the relationship between leg length and LLHR to blood pressure.

Overall height has several components (height of head, trunk length, and leg length), and some may not be sensitive to early life environment. In addition, blood pressure increases with height in children and adolescents, and is considered a factor in determining blood pressure percentile charts. However, during the age range of 9 to 14 years height changes on average by about 30 cm with larger variation (CDC Height growth charts by age for girls and boys, see Appendix B). Therefore, height alone may not be an ideal measure to examine its association with blood pressure in children and adolescents.

Leg length has demonstrated a negative association with blood pressure (Harding et al., 2010). Since leg length is considered an indicator of pre-pubertal growth, the importance of early childhood environment can be used for health promotion measures emphasizing its link to blood pressure, if a relationship is established. As highlighted by Leitch (1951), interruption of growth may lead to a long torso and relatively short legs. However, leg length alone may not reflect the ongoing growth in children and adolescents. Therefore, using a relative measure, LLHR, is expected to be better than an absolute measure (i.e., either height or leg-length alone).

Factors Related to Blood Pressure and Body Measurements

Hypertension has multiple risk factors, which include obesity, family history of hypertension, ethnic status, and other related factors (Luma & Spiotta, 2006, Sorof & Daniels, 2002). Since the present study involves peri-adolescents, it is important to take into account their physiological maturity when blood pressure and body measurements are involved. Considering developmental factors, I will explore the possibility of using years from peak height velocity (PHV) as a measure of physiological maturity in addition to other previously identified risk factors, specifically WC (as a marker for obesity), physical activity level, parent history of hypertension, socioeconomic status, and racial and ethnic background as covariates for analysis of this study.

Maturity indexes. Stature of children changes dramatically during puberty. Therefore, when adolescents are examined, it is important to consider the impact of physiological maturity. There are several maturational indexes; namely, age, skeletal age assessment, dental age, secondary sex characteristics (Tanner staging), age of peak height velocity (PHV), and years from PHV.

Since rapid physical changes occur during adolescence, whether chronological age is useful in the assessment of maturation in the peri-adolescents has been questioned (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). As well, due to cost and practical difficulties, skeletal age assessment, dental age, and secondary sexual characteristics cannot be used for screening and survey purposes.

PHV is the maximum velocity of growth during adolescence, and it is an indicator of somatic and biological growth. Age of PHV is commonly used as an indicator for maturity in longitudinal studies of adolescence. Mirwald, Baxter-Jones, Bailey, & Beunen, (2002) introduced years from PHV as a measure of maturity. Years from PHV is calculated using anthropometric measurements, and is a simple tool that can be used as a maturation index, also suitable for a cross-sectional analysis. Calculated years from PHV can be estimated using different equations for boys and girls separately (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). In boys, leg length and sitting height interaction, age and leg length interaction, age and sitting height interaction, and weight by height ratio are used in the calculation (Coefficient of determination; $R= 0.96$, $R^2= 0.915$). For girls, the prediction equation uses leg length and sitting height interaction, age and leg length interaction, age and sitting height interaction, age and weight interaction, and weight by height ratio (Coefficient of determination; R= 0.94, R^2= 0.89) (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). These calculations will be shown in the methods section. The strength of the relationship between years from PHV and skeletal maturity can be seen by their strong correlation (r= 0.83) (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002). However, there can be a limitation by using years from PHV, when there is a considerable measurement error in sitting height (Mirwald, Baxter-Jones, Bailey, & Beunen, 2002).

Additionally, LLHR and PHV overlap in its use of somatic measurements; therefore, application of years from PHV as an indicator of maturity to address the present research question may be problematic. The use of either age or years from PHV as an index of maturation will be discussed in the methods section.

Obesity/waist circumference. Several studies have shown that SBP and DBP are significantly higher in children who are obese than those who are not obese (Brion, Ness, Davey Smith, & Leary, 2007; Figueroa-Colon, Franklin, Lee, Aldridge, & Alexander, 1997; King , Meadows , Engelke, &Swanson, 2006) The results from a school based screening of 2,460, 12-16-year-old children in Texas showed that 17% of them were hypertensive, and 88% of these children had isolated SBP. Obesity was found among 23% of these children and hypertension was significantly more prevalent among the obese compared to the non obese children (33% vs 11%, p=0.0001) (Sorof, Lai, Turner, Poffenbarger, & Portman, 2004, Sorof, Poffenbarger, Franco, Bernard, & Portman, 2002).

The predictive values of body mass index (BMI) and waist circumference (WC) on blood pressure were assessed by Lara, Bustos, Amigo, Silva, & Rona, (2012) in young adults, and Papilia et al., (2012) in adolescents. It was found that both BMI and WC showed similar strength in their effect on SBP and DBP. This was seen with similar proportions of variance (R^2) for SBP when used in separate models (Lara et al., 2012). In logistic regression analyses, adjusting for age and sex, one SD increment in both, BMI and WC, resulted in the odds ratios for high SBP and DBP to be similar (OR close to 2).

Physical activity level. Physical activity among children has been shown to reduce blood pressure in pre-pubertal, obese children (Farpour-Lambert & Shi, 2009). In this randomized control trial with a modified cross over design, after 3 months of intervention of physical training, there was a significant reduction in 24-hour mean SBP. In the exercise group, the reduction in SBP was 6.9 ± 13.5 mm Hg, and, in the control group, it was 3.8 ± 7.9 mm Hg. For DBP, the reduction was 0.5 ± 1.0 mmHg, and, in the control group, it was 0 ± 1.4 mmHg. Therefore, the rate of hypertension was reduced by 12% and 1% in the exercise and control group, respectively. This study demonstrates that physical activity is an important factor in determining blood pressure.

A commonly used method to assess physical activity is the use of self- reported questionnaires due to their affordability and ease of administration. The Godin-Shephard leisure- time exercise questionnaire is a commonly used method to assess physical activity. Sallis, Buona, Roby, Micale, and Nelson (1993) reported that the relationship between week 1 and week 2 retest on the Godin Shephard total score in 5^{th}, 8^{th}, and 11^{th} grade students were 0.69, 0.80, and 0.96, respectively, and 0.81 for the total sample. There are two questions asked about the physical activity in a 7-day period. The first question asks about the frequency with which an individual engages in exercise for more than 15 minutes during free time. Total weekly leisure activity can be calculated using this first question. The second question asks how often they were engaged in regular activity to work up a sweat. The response options are often, sometimes, and never or rarely. In a review paper, Shephard (2003) described the limitations of using self-reported questionnaires which include issues related to reliability, reporting biases, and seasonal and temporal variations in physical activity patterns.

Socioeconomic status. Socioeconomic status is a vital factor in the present research. According to the American Psychological Association (2016), socioeconomic status is defined as the social standing or class of an individual or a group determined by education, occupation, and income. Several indicators of socio-economic status were found to be inversely related to blood pressure in adults (Kaplan & Kein, 1993), specifically education, occupation and income.

Among children, however, socioeconomic status is generally based on the parents' income and education level. Analysis of the Canadian Health Measures Survey (2007-2009) shows that parental education level was inversely related to blood pressure in children aged 6-17 years (Shi et al., 2012). Children whose parents had postsecondary education had lower blood pressure levels compared to those whose parents were with no postsecondary education.

However, the evidence from Shi et al., (2012) regarding the association between education and blood pressure is conflicting with regards to the association between income and blood pressure. Income was categorized into two groups comparing low income to middle and high income adjusting for the number of members in the family. Compared to the middle and high income group, the low income group showed a significant association with lower SBP Z scores among younger boys (6-11 years) and lower DBP Z scores among younger girls (6-11 years). Similarly, in boys aged 6-11 years, when compared to the middle or high income group, the low- income group had on average 0.19 mmHg lower SBP (p=0.02). However, income was not used to determine blood pressure in the adolescent group (Shi et al., 2012).

There are several subgroups identified as those with a lower socioeconomic status, for example, single mothers, aboriginal communities, new immigrants, etc. In these subgroups, children may experience adverse environmental conditions including poor nutrition, emotional disturbances, and illnesses (Franz, Lensche, & Schmitz N, 2003). As leg length is a sensitive marker of adverse environmental conditions, it is important to incorporate these subgroups when examining the relationship between LLHR and blood pressure.

Parent history of hypertension. Blood pressure tends to be higher among those who have a family history of hypertension (Munger, Prineas, & Gomez-Marin, 1988; Shi et al., 2012). According to the results of Shi et al., using the Canadian Health Measures Survey, family history of hypertension showed a positive association with SBP and DBP among children and adolescents. These associations were significant in younger girls between 6 and 11 years of age, and adolescent boys between12 and17 years of age (Shi et al., 2012).

Racial and ethnic differences. Several studies have demonstrated a difference by ethnic identification in blood pressure measurements among adolescents (Harding et al., 2010; Muntner, He, & Cutler, 2004; Sorof et al., 2004). For example, Harding et al., 2010 examined the ethnic differences in blood pressure among White British (n=692), Black Caribbean (n=670), Black African (n=772), Indian (n=384), and Pakistani and Bangladeshi (n=402) ethnicities in children 11 to 13 years of age, and 14 to 16 years of age living in England. Blood pressure changes among ethnicities were different for both sexes. Among the boys, there was no difference based on ethnic identity at 12 years of age, but Black Africans had a higher SBP than White children (+ 2.9 mmHg) at 16 years of age. Among girls, there was no significant difference in blood pressure in ethnic groups at any age. However, the change of blood pressure with age was marked in Black Caribbean and Black African children. More so, ethnic differences were marked for boys.

Likewise, the racial difference was clearly shown in The Bogalusa Heart Study in which blood pressure of Black children was significantly higher than that of White children (Voors, Foster, Frerichs, Webber, &Berenson,1976).

Summary

Stature components show a significant association with blood pressure among adults and to some extent in children. Previous research shows that height is strongly related to blood pressure in children. Leg length has been shown to have a significant negative relationship with blood pressure (Harding et al., 2010), but due to the growth of adolescents, it may be more effective to use LLHR as it is a relative measure (Wadsworth et al., 2002).

LLHR has been used in two studies in India to separately examine adolescent boys and girls to relate blood pressure levels (Rao & Apte., 2009; Rao & Kanade, 2007); it has not been used much in other geographical areas or other ethnicities. In a longitudinal study, Liu et al., (2012) used LLHR to predict overweight/obesity in Canadian children residing within the Niagara Catholic District School Board. They found that lower LLHR was linked to higher odds of overweight/obesity status after 3-year follow-up. Although LLHR is thought to represent pre-pubertal exposures, such as nutrition in early life, illnesses, and emotional disturbances (Gunnell et al., 2003), its relationship with blood pressure is unknown among Canadian children.

The objective of this study was to examine the relationship between LLHR and blood pressure in children and adolescents. The HBEAT dataset was used to test whether individuals with a lower LLHR have higher mean levels of blood pressure. It was hypothesized that there would be a negative relationship between LLHR and blood pressure among Canadian children and adolescents.

Chapter Two: Methodology

In this chapter, I describe the methodology that was used in order to achieve the objective of the study. This includes a description of the study that provided the data including study participants and variable measurements. It also discusses the statistical analytic methods and examines the effects of confounding variables.

Study Design

This cross-sectional study uses data from the Heart Behavioural and Environmental Assessment Team (HBEAT) study, a community based study conducted by researchers at Brock University. The study was carried out in 2007-2008 and 2010-2011 examining school children in grades 5 to 8 (age 9 to 14) in the Niagara Catholic District School Board (NCDSB). Ethical clearance was obtained from both Brock University and school board ethic review committees. Participation by students was voluntary. Written consent was obtained from parents and verbal consent was received from the students during their participation in the study (Appendix B). The study was funded by the Ontario Heart and Stroke Foundation.

The HBEAT study. The HBEAT study was conducted to examine the social determinants of hypertension in youth. Social determinants including socioeconomic status, diet, physical activity, psychosocial, and behavioural risk factors were examined in this study. The HBEAT study was an interventional study, which consisted of two stages (Table 4).

The first stage was conducted in the fall of 2007 and winter of 2008. In the first stage, population screening was done to measure blood pressure in children from grades 6, 7, and 8, and collect information on social determinants. The 49 elementary schools of the NCDSB in the Southern Niagara region participated.

In stage one, blood pressure measurements were used to generate tables as a reference for blood pressure percentiles depending on age, sex, and height for the study (Appendix D).

Table 4

A Schematic Presentation of the Stages of HBEAT Study

Stage 1 (fall 2007/winter 2008)			Stage 2 (spring 2010/2011)		
Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
n= 1913	n= 225		n= 689		
a population	cardiovascular	community	BP screen	Youth	
Implementation					
screen of students	health	engagement	prior to	engagement	of
intervention (blood pressure	assessment	to design		intervention	to design
and evaluation					
measurement		community-	(pre-test)	intervention	(post-
test)					
and questionnaires)		based			
		interventions			
		(Focus Groups)			

The second, intervention stage of the HBEAT study consisted of three phases. The first phase was conducted during the spring of 2010, pre-intervention, where baseline data were collected from 10 schools within the NCDSB (5 schools for intervention and 5 schools for comparison). The total target population of these 10 schools was approximately 1,200 children from grades 5 through 7. The data collection protocol followed stage one and included blood pressure screening, anthropomorphic body measurements, and parental and child surveys to collect information on social determinants of blood pressure. In the second phase of stage two, an intervention was designed using the students and peers trained for the implementation. Lastly, in the third phase, the designed intervention was implemented, and post-test data were collected in the spring of 2011, when these children were in grades 6, 7, and 8.

The current study uses only the data from the second stage, pre-intervention phase from the HBEAT study (phase one; pre-test), as these students had their stature and sitting height measured. The screen data collected in stage one did not collect sitting height measurement to calculate the leg length; therefore, it was not included in this study. Post-test data in phase three was not used because of the possible effect of the intervention implemented.

The HBEAT data from stage two, phase 1 (Table 4) drew from an expected population of 1,200 students. From these, 766 (63.8%) consented to participate in the study. Of these, 689 (89.9%) children participated in the total data collection protocol at the school. Details of the sampling strategy are presented in Appendix E. The information collected included demographic variables, blood pressure and body measurements (height, body mass, hip and waist circumference, and sitting height). In addition, they also completed the Godin-Shephard physical activity scale during their 15-minute rest period prior to having their blood pressure taken.

Finally, of the 689 students who participated in school testing, 466 parents (67.63 %) returned a completed questionnaire that included the information regarding parental education level and parental history of hypertension. However, only 460 participants had information without missing values on the key variables. Therefore, parent education and history of hypertension will be used in a sub analysis for those who had the parental information through the returned questionnaires. Sampling strategy for the phase 1 of stage 2 is given in Figure 2.

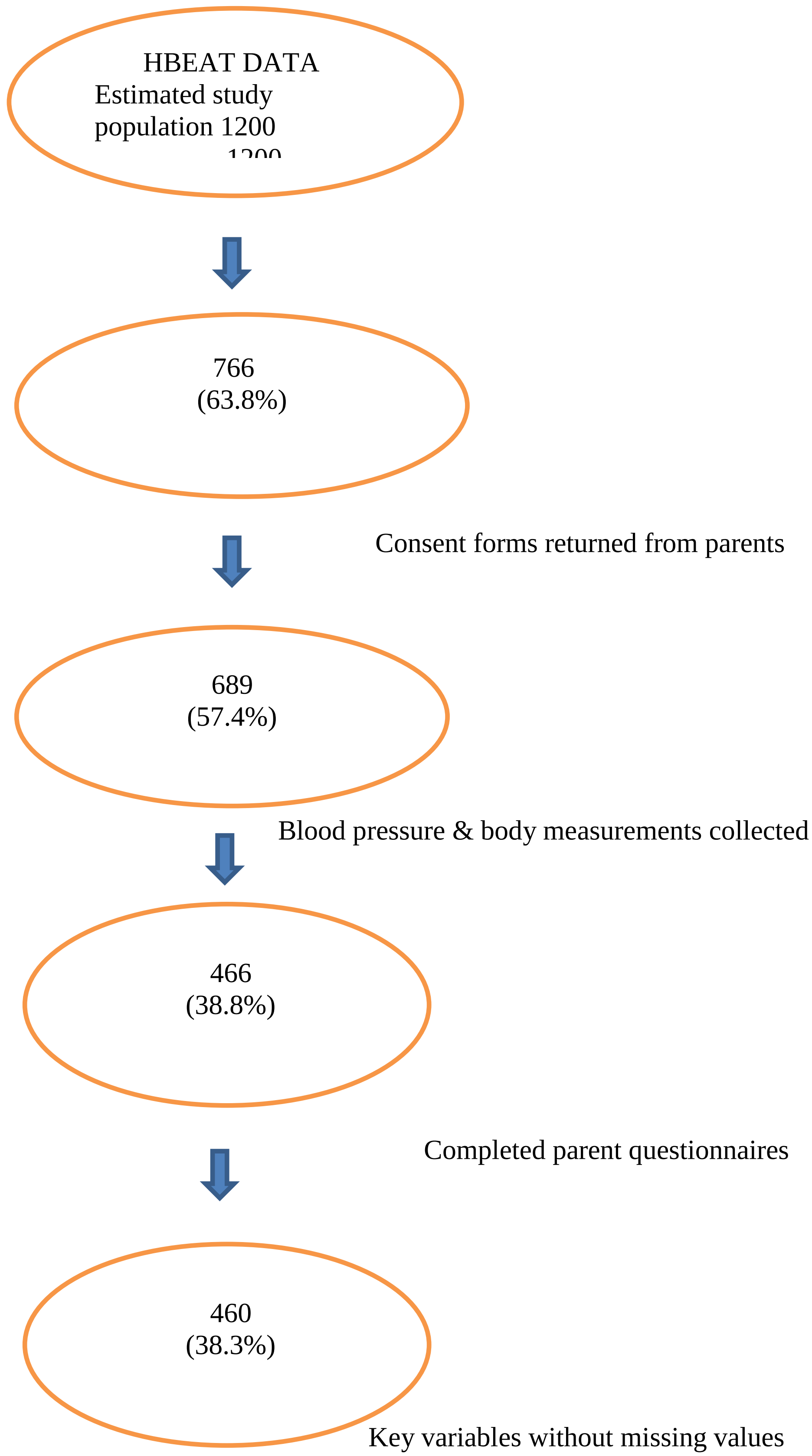

Figure 2. A schematic representation of data cleaning steps in stage 2.

Measurements

Blood pressure. Blood pressure measurements were taken in a quiet setting in the library after the participants had been sitting in a relaxed position for 15 minutes. Blood pressure measurements were taken using an automated oscillometric device (BPM-300, VSM MedTech Devices Inc., Coquitlam, B.C., Canada). Cuff size was selected based on the size of the child's arm. Skilled research assistants took six sequential measurements of SBP and DBP at 1-minute intervals. This was done on the right arm with the cuff placed at heart level. The first three readings were taken to familiarize the students with the procedure and were subsequently discarded. The last three measurements were used to calculate the average SBP and DBP. If there was an error, two manual readings were taken using a sphygmomanometer. PP was calculated as the difference between the average SBP and DBP measurements. MAP was obtained by using the equation of "DBP+ (1/3 PP)". Students with high blood pressure were identified by blood pressure being $\geq 95^{th}$ percentile, while those with borderline high blood pressure were identified by blood pressure being$>90^{th}$but $<95^{th}$ percentile.

For this study, the percentiles of blood pressure cut-offs were made using the blood pressure measurements taken in stage 1 from 50 schools of NCDSB (Appendix C).

Stature and weight. In the HBEAT study, body height and weight were taken by research assistants after the blood pressure measurements. A stadiometer (Invicta Plastics Limited, Leicester, England) was used for the height measurement. Three height measurements were taken and used to calculate the average following the National Health and Nutrition Examination Survey (NHANES, 2013) protocol. In NHANES, it was measured by placing the person straight against the stadiometer, with both heels together touching the base of the vertical board (Figure 3). The front feet were slightly placed outward (60- degree angle) with the buttocks, scapulae, and head touching the vertical board. The person was asked to inhale fully and the examiner lowered the horizontal bar to the crown of the head applying a pressure to compress the hair. Then the bar was locked and the measurement was marked on the vertical tape to record the height to the nearest 0.1 cm. In the HBEAT study, height measurement was taken using the method as described above. Participants were standing with eyes forward, shoulders relaxed and arms down, and without footwear.

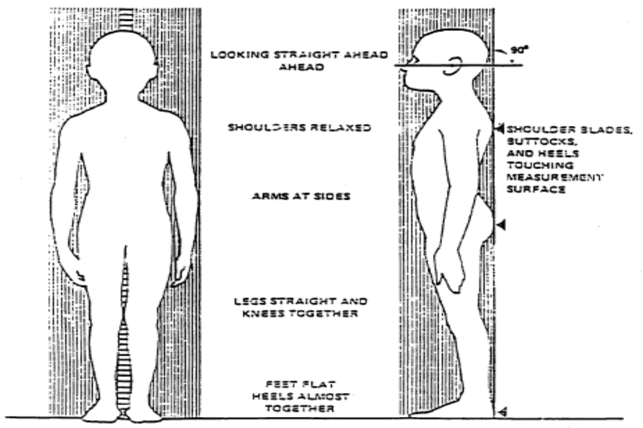

Figure 3. Reprinted from Centre for Disease Control demonstrating how to measure standing height.

Sitting height was measured from the vertex of head to the buttocks in the seated position. In the HBEAT study, children were asked to sit on the floor, with straight legs. The measurement was taken as the distance from the floor to the vertex, to the nearest 0.1 cm. Three measurements were collected for sitting height; of them the first two were measured and considered as accurate. The third measurement was later recognized as having mostly outliers possibly due to incorrect data entry. Therefore, for this current study, sitting height was considered as the average of the first and second sitting height measurements. Leg length was calculated by subtracting sitting height from the average height. LLHR was obtained by dividing leg length by height.

Body weight was measured using a calibrated electronic medical scale (BWB-800S, Tanita Corporation, Tokyo, Japan), to the nearest 0.1 kilograms. Again, three measurements were taken to calculate the average.

BMI was calculated using body mass (kg) divided by height (m^2). WC was recorded while participants were relaxed, standing upright, heels together, and arms in the resting position. It was measured around the narrowest point of the waist (approximately around the belly button). A flexible inelastic tape was used to obtain a measure of WC to the nearest 0.2 cm. Three measurements were taken and averaged as the final WC.

WC was selected to indicate obesity over BMI to overcome the overlapping of LLHR and BMI as height is used to calculate both factors. However, there was a negative, weak correlation between LLHR and BMI ($r = -0.131$; $p < 0.0007$).

The age of the children in this study ranged from 9 to 14 years, with a mean of 11.2 years (SD=0.9). Due to the overlap of pubertal stage within this age range, it is essential to adjust the analysis for maturity. As described by Mirwald, Baxter-Jones, Bailey, & Beunen, (2002), there are several measures that can be considered (Described in Chapter 1); among them, chronological age and years from PHV are measures that can be used as maturation indexes, especially in surveys. Years from PHV is calculated using age, leg length, sitting height, weight, and height.

Maturity offset (Boys) = -9.236 + 0.0002708 Leg length and Sitting height interaction- 0.001663 Age and Leg length interaction + 0.007216 Age and Sitting height interaction + 0.02292 Weight by height ratio

Maturity offset (Girls) = -9.376 + 0.0001882 Leg length and Sitting height interaction + 0.0022 Age and Leg length interaction + 0.005841Age and Sitting height interaction – 0.002658 Age and Weight Interaction + 0.07693 Weight by height ratio

In this present study, LLHR is calculated using sitting height and standing height. Therefore, there is an overlap in the LLHR and years from PHV measures with a suspected high correlation. When examined, the correlation of LLHR and Years from APH, surprisingly demonstrated a nonsignificant weak, positive correlation ($r= 0.061$; $p= 0.1181$). In the preliminary analysis between LLHR and blood pressure correlation and regression models showed slightly stronger relationship and better significance when controlled for age instead of years from PHV. Therefore, an individual's age will be used instead of years from PHV as an index of maturity.

Questionnaire Data

Questionnaires were used to gather information from both the students and their parents. Demographic variables, physical activity data, eating patterns, and parental disease status were among the information collected. The questionnaire data that this study focussed on are listed below.

Child's physical activity level. Students reported their activity level based on the Godin–Shephard leisure-time exercise questionnaire, which included two questions. The second question was used to proxy the participants' physical activities, asking how often they were involved in regular activity during leisure time in a 7-day period. There were three responses; often, sometimes, and never/rarely. Due to the simplicity of this question, it was thought to have the advantage of being less confusing to the participant, considering the age range of the participants. Therefore, the second question was used for the analysis.

Socioeconomic status. Parental education and income are the two most important variables representing socioeconomic status. This information was gathered using the parent questionnaire. Family education was coded to indicate highest level of education of either the mother or father and was categorized into six groups. The groups were: grade 11 or less, grade 12, high school diploma, partial college or training, college or undergraduate degree, graduate degree, or professional training. The income variable had more than 50% missing observations and, therefore, was not used in the analysis.

Parental history of hypertension. Information on family medical history was obtained through a series of questions asked of the parents in the questionnaire, including medical diagnoses of hypertension, high cholesterol, diabetes, and heart disease. Among the medical conditions referenced using the questionnaire, history of hypertension among the parents was used for this study. This was coded as a dichotomous variable with response options to indicate no history, or history of hypertension in either parent.

Demographic variables. Demographic information was collected through the parent and child questionnaires (Appendix F). Student's age (years), sex, and information on general well-being were collected using the child's questionnaire. Race and ethnicity have shown to have an effect on both blood pressure and body measurements. However, the overwhelming majority of participating families indicated that they were Caucasians which did not provide sufficient variance for analysis. Therefore, it was not possible to examine the role of race or ethnicity in this analysis.

Statistical Analysis

The purpose of this study was to examine the relationship between blood pressure measurements (SBP, DBP, PP, & MAP) and LLHR. All analyses were carried out using Statistical analysis software (SAS 9.4version), and level of significance for all measures was set at $p \leq 0.05$ (two-tailed).

Missing values and attrition analysis. There were missing values for the variables of parental information as a limited number of surveys were returned. Table 5 shows the number of missing values in each key variable.

Table 5

Frequency of Missing Values in the Key Variables of HBEAT Study Sample

Variable	Frequency missing
Blood pressure	
SBP	6
DBP	6
Weight	29
Waist circumference	1
Physical activity	1
Parent history of hypertension	224
Parent education	225

SBP Systolic blood pressure
DBP Diastolic blood pressure

Attrition analyses were performed in two steps. First, those participants who gave consent but did not participate in blood pressure and body measurements, and those who participated in the measurements were compared with regard to age using an independent-samples t-test. Attrition rate was 9.2%. The students who did not participate had a mean age of 10.7 years (SD 0.8) and those who participated had a mean age of 11.2(SD 0.95; $p< 0.0001$).

Sex was not known until the participants took part in the study; therefore, sex was set by default as females. Of the 766 who returned the consent forms, 689 participated in the study. Of the 689 students, 50.36% were females and 49.64% were males.

Secondly, participants who had the completed parent questionnaire and those who did not were compared with respect to age, sex, LLHR, and blood pressure measurements (Table 6). This examined whether the subsample used for this study was representative of the study population. There were 460 in the group with parent questionnaires and 229 in the group without parent questionnaires. Attrition rate was 33.2%. Mean age was slightly higher in those who returned the completed parent questionnaire, but mean LLHR was slightly lower. Sex distribution was statistically different in the two groups as well ($p<0.0001$). Of those who had parent questionnaire, 56.6% were females, and in those who did not, only 37.33% were females. However, blood pressure measurements were not significantly different between the two groups compared.

Table 6

Comparison of Basic Characteristics Between Participants Who Had Parent Questionnaires and Those Who Did Not in the HBEAT Study

	Had parent questionnaires N=460	Did not have parent questionnaires N=229	
Age (mean/ SD; years)	11.3 (0.9)	11.0 (0.8)	p<0.0004
Sex (Frequency/%)			
Male	204 /43.4	141/ 62.6	p <0.001
Female	266/ 56.6	84 /37.3	
LLHR	0.49 (0.02)	0.48 (0.01)	p <0.05
SBP (mmHg)	91 (8)	91 (8)	NS
DBP (mmHg)	56 (8)	55 (7)	NS
PP (mmHg)	35 (6)	35 (7)	NS
MAP (mmHg)	67 (7)	66 (7)	NS

NS: Not Significant
N: sample size
LLHR: Leg length to height ratio
SD: Standard deviation
SBP: Systolic blood pressure
DBP: Diastolic blood pressure
PP: Pulse pressure (SBP- DBP)
MAP: Mean arterial pressure (DBP + 1/3 PP)

Assumption checks. For the total sample, the skewness was 0.539 for SBP, 1.024 for DBP, 0.055 for PP, and 0.91 for MAP (the detail of normality assumption check are shown in Appendix G). Since none of the skewness value was larger than 2, all analyses were performed under the assumption that normal distribution of data was met (Hae-Young Kim, 2013; West, Finch, & Curran, 1995). The sub sample that had the parent questionnaire also showed similar skewness, however, normality assumption was assumed (shown in Appendix G).

Steps of analysis. PP and MAP were calculated using the SBP and DBP taken from the participants. SBP, DBP, PP, and MAP were the four dependent variables, and every analysis was done for these four blood pressure measurements.

Basic characteristics of the study sample were described including: age, sex, family education, body measurements, and blood pressure measurements. Initially, basic characteristics were compared by sex using independent sample t-test for continuous data and Chi-square statistics for categorical data, where appropriate. Since the risk association is similar between sexes (see results below), subsequent analyses were done combining both sexes.

Scatter plots were used to detect a linear or nonlinear relationship between the blood pressure measurements and LLHR (Appendix H).

The correlation between all blood pressure measurements and LLHR was evaluated using Pearson correlation. In another model, correlation matrices were computed controlling for age, sex, WC, physical activity, family education, and parental history of hypertension for the total sample. Correlations between blood pressure measures were also calculated.

For the regression models, all four blood pressure measurements were used as dependent variables. Two strategies were used to handle LLHR as the independent variable. First, standard deviation of LLHR was used as a unit of measure in increments (continuous measure). Secondly, LLHR tertiles were generated to compare the tertiles and look for of blood pressure change with increasing LLHR tertile, and to detect any nonlinear relationship. Adjusted means of blood pressure measurements of the tertiles of LLHR were used to examine any significant differences in average blood pressures across the three tertiles of LLHR.

Regression models began with simple linear regression analysis to examine the association between blood pressure and LLHR for the overall sample. The strategy for building the models for multiple regression analysis is shown in Table 7 for the n= 689 sample. Regression models were generated looking at the significance and the improvement in the variability of blood pressure measurements. The covariates used were age, WC, and physical activity.

Table 7

Regression Modeling Strategy for LLHR for the Total Sample with LLHR One SD Increase

Models	Predictors
Model 1	LLHRSD
Model 2	LLHRSD & Age
Model 3	LLHRSD, Age & Sex
Model 4	LLHRSD, Age, Sex & WC
Model 5	LLHRSD, Age, Sex, WC & Child's Physical Activity Level

LLHRSD: Standard deviation of leg length to height ratio

Modelling strategy for the sub analysis in those who have the parental data without missing values (n=460) was done according to Table 8. Family education and parent history of hypertension were used from the parent questionnaire.

Table 8

Regression Modeling Strategy for LLHR for the Subsample with LLHR One SD Increase

Models	Predictors
Model 1	LLHRSD
Model 2	LLHRSD, Age, Sex, WC & Child's Physical Activity Level
Model 3	LLHRSD, Age, Sex, WC, Child's Physical Activity Level & Family Education
Model 4	LLHRSD, Age, Sex, WC, Child's Physical Activity Level, Family Education & Parent History of Hypertension

LLHRSD: Standard deviation of leg length to height ratio

Chapter Three: Results

Basic Characteristics of Study Sample

The study sample was comprised of the participants in the stage two, phase one component of the HBEAT study. In 2010, students between 9-14 years of age, in grades 5, 6, and 7 from 10 schools of NCDSB comprised the target study sample. Written consent was obtained from parents (Appendix B) and verbal consent was received from the students. Basic characteristics of the study sample are presented in Table 9.

Table 9

Basic Sample Characteristics

		N	Mean (SD)	Percentages
Age (years)		689	11.2 (0.9)	
Sex (Male %)		689		
Age (number and %)		689		
	9	3		0.4
	10	219		26.5
	11	238		31.6
	12	248		33.5
	13	53		7.7
	14	1		0.2
Family Education (%)		460		
Grade 11 or Less				1.5
Grade 12				6.4
High School Diploma				8.3
Partial college/ training				17.8
College or undergraduate degree				45.9
Graduate degree or prof. training				20.1
Years from PHV (years)		657	-2.7 (0.7)	
Height (cm)		689	150.8 (9.5)	
Sitting Height (cm)		689	77.7 (4.9)	
Leg Length (cm)		689	73.1 (5.7)	
LLHR (%)		689	48.4 (1.6)	

Body mass (kg)	660	46.3 (12.8)	
BMI (kg/m²)	660	20.0 (4.2)	
Obesity (%)	660		
Normal			67.4
Overweight			23.8
Obese			8.7
WC(cm)	689	71.3 (11.4)	
Physical Activity (%)	684		
Often			56.6
Sometimes			41.2
Never/rarely			2.1
SBP (mmHg)	689	91 (8)	
DBP (mmHg)	689	55 (7)	
PP (mmHg)	689	35 (7)	
MAP (mmHg)	689	67 (7)	
Blood Pressure Status (%)	689		
Normal			98.4
Pre-hypertensive			0.4
Hypertensive			1.2
Parent Hypertension (%)	460		15.3

SD: Standard deviation
PHV: Peak height velocity
LLHR: Leg length to height ratio
BMI: Body mass index
SBP: Systolic Blood Pressure
DBP: Diastolic blood pressure
PP: Pulse Pressure
MAP: Mean Arterial Pressure

Effect of Sex on the Relationship Between Blood Pressure Measurements and LLHR

Due to biological differences between sexes, the basic characteristics were compared between males and females, as shown in Table 10.

Table 10

Comparison of Basic Characteristics Between Boys and Girls (N=689)

Variable	Boys (n=342)	Girls (n=347)	p-value
Age	11.3	11.0	0.69
Sex (%)	49.6	50.4	0.86
Mean Height (cm)	150.8	151	0.77
Mean Sitting Height (cm)	77.1	78.3	0.0008
Mean Leg Length (cm)	73.6	72.6	0.016
Mean LLHR (%)	49	40	<0.0001
Body Mass (kg)	46.1	46.5	0.74
BMI	19.9	20.1	0.62
WC	71.3	71.4	0.45
P/A			
Often	60.8	53.1	0.11
Sometimes	37.2	44.5	
Never/rarely	0.3	2.3	
SBP(mmHg)	90	90	0.89
DBP(mmHg)	55	55	0.58
PP(mmHg)	35	35	0.24
MAP(mmHg)	67	67	0.76

LLHR: Leg length to height ratio
BMI: Body mass index
WC:
SBP: Systolic Blood Pressure
DBP: Diastolic Blood Pressure
PP: Pulse Pressure
MAP: Mean Arterial Pressure

Recognizable differences were observed in the mean sitting height, leg length and LLHR between males and females ($p < 0.05$). None of the blood pressure measurements showed any significant difference between males and females.

Age did not show a significant difference. The age range of these students was 9-14 years of age. Subsequently, in regression analyses, sex did not show significant effects in any of the models for all four blood pressure measurements. Therefore, analysis was performed for the overall sample with both sexes combined.

The basic characteristics of the subsample were analysed to see any significant difference between sexes; only mean sitting height, leg length, and LLHR were significantly different.

Correlation

Correlation between blood pressure and LLHR. Pearson correlation was used to assess the correlation between blood pressure measurements and LLHR. (Table 11)

Table 11

Correlation Matrices Between Blood Pressure Measurements and LLHR

	Unadjusted Corr. Coef. (Model 1) N=689	Adjusted Corr. Coef. (Model 2) N=683	Adjusted Corr. Coef. (Model 3) N=460
SBP (mmHg)	-0.07*	-0.09**	-0.08
DBP(mmHg)	-0.09	-0.10	-0.13**
PP(mmHg)	-0.01	-0.02	0.02
MAP(mmHg)	-0.08*	-0.11**	-0.13**

SBP: Systolic Blood Pressure
DBP: Diastolic blood pressure
PP: Pulse Pressure
MAP: Mean Arterial Pressure
*Significant at p<0.05
**Significant at p<0.01
Corr. Coef: Correlation coefficient
Model 1: Unadjusted
Model 2: Adjusted for age, sex, waist circumference, and physical activity
Model 3: Adjusted for age, sex, waist circumference, physical activity, family education and parent history of hypertension

Correlation matrices were generated in three models. In the unadjusted analysis, SBP, DBP, PP, and MAP had a negative, weak linear relationship with LLHR; only DBP and MAP were statistically significant. After adjusting for age, sex, WC and physical activity level, negative, weak linear relationships remained in SBP, DBP, and MAP as seen in Table 10. In the fully adjusted model, only DBP and MAP showed significant weak, negative correlations.

Correlation between blood pressure measurements. There were strong correlations between MAP and SBP ($r=0.842$; $p<0.001$), MAP and DBP ($r=0.957$; $p<0.001$), and moderate correlations between SBP and DBP ($r= 0.650$; $p<0.001$). PP showed a positive moderate correlation with SBP ($r=0.487$; $p<0.001$), a negative moderate correlation with DBP ($r=-0.345$; $p<0.001$). PP did not correlate with MAP ($r=-0.059$; $p=0.1169$).

Multiple Regression Models

The objective of this study was to assess the association between blood pressure and LLHR. To ascertain this relationship, two strategies were used. One method was to use LLHR as a continuous measurement using its standard deviation as a unit change; another was to use tertiles of LLHR to compare blood pressure between groups.

Multiple regression models with LLHR as a continuous measure. First, regression models were built for the overall sample of 689 students for SBP, DBP, PP, and MAP as dependent variables, and with LLHR as the independent variable using its SD as an increment. Table 12 provides the parameter estimates for the multiple regression models for SBP.

Table 12

Multiple Regression Models for SBP with LLHD I SD Increment (n=689)

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	114.02	97.91	103.67	91.46	93.33
R^2	0.01	0.06	0.06	0.18	0.18
Adj. R^2	0.01	0.05	0.05	0.17	0.17
LLHRSD	-0.73**	-0.89**	-1.09	-1.02**	-1.05**
Age		1.88**	1.90**	1.17**	1.16**
Sex			1.10	1.02	1.03
WC				0.25**	0.25**
Physical Activity					0.12

* Significant at $p<0.05$
** Significant at $p<0.01$
LLHRSD: Leg Length to Height Ratio standard deviation
R^2: Coefficient of determination
Adj. R^2: Adjusted Coefficient of determination
Model 1: Unadjusted
Model 2: Adjusted for age
Model 3: Adjusted for age and sex
Model 4: Adjusted for age, sex and waist circumference
Model 5: Adjusted for age, sex, waist circumference and physical activity

SBP showed a negative association with LLHRSD. Change in SBP was evaluated with an increment of SD of LLHR. When LLHR increased by 1 SD, SBP decreased by 0.73 mmHg in the unadjusted model (R^2= 1.1 %). When adjusted for age and sex SBP showed a 1.09 mmHg reduction with one SD increase in LLHR (R^2=6.1 %). In the fully adjusted model, the variance (adjusted R^2) increased to 18.0 %. Similar results were seen with DBP (Table 13) and MAP (Table 14). The strength of the association increased with each covariate added to the models. Adjusted R^2 increased from model one through to model five. Age showed a significant positive association in all models, but sex showed no significant effect. However, PP did not show a similar relationship (Table 14).

Table 13

Multiple Regression Models for DBP with LLHR One SD increment (n=689)

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	74.92	64.98	67.09	61.04	64.10
R^2	0.01	0.03	0.03	0.06	0.08
Adj R^2	0.01	0.03	0.03	0.05	0.07
LLHRSD	-0.61*	-0.71**	-0.78**	-0.75**	-0.85**
Age		1.17**	1.18**	0.83**	0.79**
Sex			0.40	0.35	0.38
WC				0.13**	0.13**
Physical activity					0.28**

* Significant at p <0.05
** Significant at p <0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
Model 1: Unadjusted
Model 2: Adjusted for age
Model 3: Adjusted for age and sex
Model 4: Adjusted for age, sex and waist circumference
Model 5: Adjusted for age, sex, waist circumference andphysical activity

DBP showed a significant negative relationship with increasing SD of LLHR. When LLHR increased by one SD, DBP decreased by 0.61 mmHg in the unadjusted model, while DBP reduced by 0.85 mmHg in the fully adjusted model.

Table 14

Multiple Regression Models for PP with LLHR 1 SD Increment (n=689)

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	39.10	32.92	36.57	30.41	28.22
R^2	0.00	0.01	0.01	0.06	0.07
Adj R^2	-0.00	0.01	0.01	0.05	0.06
LLHRSD	-0.12	-0.17	-0.31	-0.26	-0.19
Age		0.71**	0.72**	0.34	0.36
Sex			0.69	0.66	0.65
WC				0.12**	0.12**
Physical Activity					-0.16*

*   Significant a p <0.05
** Significant at p<0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
LLHR: Leg Length to Height Ratio Standard Deviation
Model 1: Unadjusted
Model 2: Adjusted for age
Model 3: Adjusted for age and sex
Model 4: Adjusted for age, sex and waist circumference
Model 5: Adjusted forage, sex, waist circumference and physical activity

Table 15

Multiple Regression Models for MAP with LLHR 1 SD Increment (n=689)

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	87.95	75.95	79.29	71.18	73.51
R^2	0.01	0.04	0.05	0.11	0.13
Adj R^2	0.01	0.04	0.04	0.11	0.12
LLHRSD	-0.65**	-0.77**	-0.89**	-0.84**	-0.92**
Age		1.41**	1.42**	0.94**	0.92**
Sex			0.63	0.58	0.59
WC				0.16**	0.17**
Physical activity					0.23**

*   Significant at p< 0.05
** Significant at p< 0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination

LLHRSD: Leg Length to Height Ratio Standard Deviation
Model 1: Unadjusted
Model 2: Adjusted for Age
Model 3: Adjusted for Age and Sex
Model 4: Adjusted for Age, Sex and Waist Circumference
Model 5: Adjusted for Age, Sex, Waist Circumference and Physical Activity

With one SD increment of LLHR, MAP decreased by 0.65 mmHg in the unadjusted model, continued to have a significant, negative relationship with addition of each covariates. In the fully adjusted model, MAP reduced by almost 1 mmHg when increasing LLHR by one SD.

Subsample analysis. The subsample was comprised of participants who had returned the completed parent questionnaires. This sub analysis was performed using multiple regression analysis to examine the association between LLHR and blood pressure with adjustments to the previous covariates as well as consideration of family education and parent history of hypertension. (Table 16)

Table 16

Multiple Regression Models for SBP with LLHR 1 SD Increment for the Subsample

	Model 1	Model 2	Model 3	Model 4
	(N=460)	(N=460)	(N=460)	(N=460)
Intercept	122.30	93.32	95.45	96.31
R^2	0.01	0.16	0.17	0.17
Adj R^2	0·01	0.15	0.16	0.15
LLHRSD	-0.99	-0.96	-0.94*	-0.95*
Age		0.89*	0.86*	0.82*
Sex		0.41	0.42	0.37
WC		0.24**	0.24**	0.24**
Physical Activity		-0.17	-0.17	-0.23
Family Education			-0.44	-0.44
Parent History of Hypertension				0.07

*   Significant at p<0.05
** Significant at p<0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
LLHRSD: Leg Length to Height Ratio Standard Deviation

Model 1: Unadjusted
Model 2: Adjusted for Age, Sex, Waist Circumference and Physical Activity
Model 3: Adjusted for Age, Sex, Waist Circumference and Physical Activity& Family Education
Model 4: Adjusted for Age, Sex, Waist Circumference and Physical Activity, Family Education & Parent History of Hypertension

Family education had six categories ranging from less than grade 11 through to graduate level or professional training. Both family education and parent history of hypertension did not have significant effects on SBP. With the addition of parent education and parental history of hypertension to the model, the relationship between SBP and physical activity showed opposite results than the total sample (Table 17).

Table 17

Multiple Regression Models for DBP with LLHR 1 SD Increment for the Subsample

	Model 1 (N=460)	Model 2 (N=460)	Model 3 (N=460)	Model 4 (N=460)
Intercept	77.46	74.00	76.85	77.97
R^2	0.03	0.08	0.09	0.09
Adj R^2	0.03	0.07	0.08	0.07
LLHRSD	-1.03**	-1.10**	-1.08**	-1.09**
Age		0.52	0.48	0.45
Sex		0.75	0.77	0.72
WC		0.14**	0.14**	0.14*
Physical Activity		-0.01	-0.02	- 0.07
Family Education			-0.60*	- 0.61*
Parent History of Hypertension				- 0.04

* Significant at p<0.05
** Significant at p<0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
LLHR: Leg Length to Height Ratio Standard Deviation
Model 1: Unadjusted
Model 2: Adjusted for Age, Sex, Waist Circumference and Physical Activity
Model 3: Adjusted for Age, Sex, Waist Circumference and Physical Activity &Family Education
Model 4: Adjusted for Age, Sex, Waist Circumference and Physical Activity, Family Education &Parent History of Hypertension

In the fully adjusted model, DBP was 1.09 mmHg lower with one SD increase in LLHR. Only WC showed significant results. In model 3, when family education was introduced to the model, there was still a significant negative relation with DBP. (Table 18)

Table 18

Multiple Regression Models for PP with LLHR 1 SD Increment for the Subsample

	Model 1 (N=460)	Model 2 (N=460)	Model 3 (N=460)	Model 4 (N=460)
Intercept	35.37	19.30	18.50	18.33
R^2	0.00	0.04	0.04	0.04
Adj R^2	0.00	0.03	0.03	0.03
LLHRSD	-0.01	0.14	0.14	0.14
Age		0.36	0.37	0.37
Sex		-0.34	- 0.34	-0.34
WC		0.10**	0.10**	0.11**
Physical Activity		-0.16	-0.16	- 0.16
Family Education			0.15	0.16
Parent History of Hypertension				0.11

* Significant at p<0.05
** Significant at p<0.01
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
LLHRSD: Leg Length to Height Ratio Standard Deviation
Model 1: Unadjusted
Model 2: Adjusted for Age, Sex, Waist Circumference and Physical Activity
Model 3: Adjusted for Age, Sex, Waist Circumference and Physical Activity & Family Education
Model 4: Adjusted for Age, Sex, Waist Circumference and Physical Activity, Family Education & Parent History of Hypertension

Table 19

Multiple Regression Models for MAP with LLHR 1 SD Increment for the Subsample

	Model 1 (N=460)	Model 2 (N=460)	Model 3 (N=460)	Model 4 (N=460)
Intercept	98.72	80.44	83.05	84.08
R^2	0.02	0.12	0.13	0.13
Adj R^2	0.02	0.11	0.12	0.12
LLHRSD	- 0.99**	- 1.06**	-1.04**	- 1.05**
Age		0.64	0.61	0.57
Sex		0.63	0.65	0.60
WC		0.18**	0.17**	0.17**
Physical Activity		-0.06	-0.07	- 0.12
Family Education			-0.55*	- 0.55*
Parent History of Hypertension				- 0.01

* Significant at $p<0.05$
** Significant at $p<0.01$
R2: Coefficient of Determination
Adj. R2: Adjusted Coefficient of Determination
LLHRSD: Leg Length to Height Ratio Standard Deviation
WC: Waist Circumference
Model 1: Unadjusted
Model 2: Adjusted for Age, Sex, Waist Circumference and Physical Activity
Model 3: Adjusted for Age, Sex, Waist Circumference and Physical Activity & Family Education
Model 4: Adjusted for Age, Sex, Waist Circumference and Physical Activity, Family Education & Parent History of Hypertension

In the subsample regarding PP, family education and parent history of hypertension had positive associations. MAP continued to show significant negative associations with one SD increase of LLHR, when family education and parent history of hypertension were added to the models. Family education showed a significant relationship with MAP. When family education was one level higher, MAP reduced by 0.55 mmHg. Parent history of hypertension did not show a significant effect on MAP.

Comparison of blood pressures among tertiles of LLHR. Another step in the analysis was to categorize LLHR by tertiles to see the effects on blood pressure. The tertiles of LLHR were between 0.417 and 0.477, 0.477and 0.489, and 0.489 and 0.589. Blood pressure measurements were arranged by the tertiles of the LLHR and are demonstrated in Table 20. Adjusted means procedure was used to compare the average of blood pressure by tertiles of LLHR controlled for age and sex.

Table 20

Blood Pressure Measurements (mmHg) By Tertiles of LLHR Adjusted for Age and Sex

	Tertile 1 (n= 230)	Tertile 2 (n= 230)	Tertile 3 (n=229)	p value
SBP	91*	90	89*	0.034
DBP	56	55	54	0.071
PP	35	35	35	0.867
MAP	68*	67	66*	0.029

* Significant comparisons
SBP: Systolic blood pressure
DBP: Diastolic blood pressure
PP: Pulse pressure
MAP: Mean arterial pressure

When moving from tertiles 1 to 3, SBP, DBP, PP, and MAP decreased gradually exhibiting the inverse relationship between blood pressure and LLHR. Adjusted means of SBP, DBP, PP, and MAP were compared to see any significant differences in blood pressure among the tertiles.

In SBP, there was a significant difference between mean of SBP in tertile 1 and tertile 3 of LLHR (p= 0.034). MAP showed similar results indicating a significant difference in the mean MAP in tertile 1 and tertile 3 of LLHR (p=0.029). In both SBP and MAP, the difference in blood pressure between tertile 1 and tertile 3 was about 2mmHg.

Effects of Covariates

Age. Results of this cross sectional study showed that all blood pressure measurements increased with the increasing age of participants. In all the models of the initial sample and the subsample, age showed positive associations with blood pressure measurements indicating significant results in most models.

Waist circumference. In all models, WC showed a positive relationship with all four blood pressure measurements. In addition, it was observed that when moving from tertile 1 to 3, the percentage of those that were normal weight increased while the percentages of overweight and obese decreased (According to Cole's cut-offs of BMI, Coles et al., 2000) (Table 21).

Table 21

Percentages of Obesity Status (%) by Tertiles of LLHR

	Tertile 1 (n=230)	Tertile 2 (n=230)	Tertile 3 (n=229)
Normal BMI	19.8	22.5	25.1
Overweight	9.2	7.6	7.1
Obese	4.4	2.5	1.8

Physical activity. This analysis used the student questionnaire to obtain information about physical activity. The question used in this study was a categorical measure asking how often in a week the participant engaged in regular activity during leisure time. The three categories were: often, sometimes, and never or rarely. The results from the total sample showed that, when physical activity category moved from often to sometimes to never or rarely, SBP, DBP, and MAP increased. However, only DBP and MAP demonstrated significance. PP showed a negative relationship, which was not significant. In the subsample with the parent questionnaire, SBP, DBP, and MAP had a negative relationship with physical activity, showing opposite results.

Family education. In the HBEAT study, family education had six categories (Table 9). When family education increased, SBP and PP increased while DBP and MAP reduced. However, only DBP and MAP achieved statistical significance.

Parent history of hypertension. Parent history of hypertension had two categories; those with hypertension and without hypertension. The results did not show any significant effects on blood pressures with respect to parental history of hypertension in this study sample.

Chapter Four: Discussion

This cross-sectional analysis was based on the HBEAT study, 2010 data, from 689 students in 10 schools across the NDCSB. This is the first study that has been done in Canada to examine the association between LLHR and blood pressure in youth.

Summary of Results

A negative correlation between LLHR and SBP, DBP and MAP was observed in this study even after adjusting for a number of potential confounding variables. When LLHR was categorized into tertiles, a negative association was observed for all blood pressure measurements; however, only SBP and MAP reached statistical significance.

Blood pressure showed a positive relationship to age and WC; physical activity showed a negative relationship (DBP and MAP reaching significance). Parental education showed an impact on DBP and MAP; children whose parents had a higher education had lower blood pressure levels. However, history of parent hypertension seemed not to be associated with any blood pressure measurement in the youth population participating in this study.

Relation to Other Research

The present study observed negative associations between blood pressure measures (SBP, DBP, PP, and MAP) and LLHR among a Canadian peri-adolescent population, confirming the results seen in Rao and Apte, (2009), Rao and Kanade, (2007) and Liu et al., (2014). There has been no research done directly using LLHR and blood pressure in adults; however, studies show a trend between other stature components (leg length, height and leg length to trunk ratio) and blood pressure, as well as other CVD risk factors (Gunnell et al., 2003; Langenberg et al., 2005; Regidor et al., 2006; Schooling et al., 2007).

However, in the present study, the variance explained by the models was very small (R^2 = 0.06-0.18), even in those blood pressure measurements which gave significant results (SBP, DBP, and MAP). Also, when mean blood pressures were compared between the tertiles of LLHR, blood pressure reduced when moving from tertile 1 to tertile 3. However, there was only a 2 mmHg difference recorded between the first and third tertiles of SBP and MAP, even though they were statistically significant. The question to highlight is whether this 2 mmHg difference is of any clinical importance. Zanchetti, Thomopoulos, & Parati (2015), in a meta-analysis examined blood pressure reduction and risk reduction of stroke, cardiovascular events, cardiovascular mortality and all -cause mortality. Using a standardizedblood pressure difference of SBP/DBP of 10/5 mmHg, between active and placebo groups, the risk of stroke, heart failure, coronary heart disease, cardiovascular mortality and all-cause mortality were reduced by 36%, 43%, 16%, 18% and 11% respectively. Therefore, 2 mmHg is not of clinical significance.

Likewise, in a study conducted by Langenberg et al., 2005, there were only minimal changes in blood pressure with one unit increment of height, leg length, and LLHR. For example, when leg length increased by 1 cm, SBP and PP reduced by about 0.02mmHg (Langenberg et al., 2005).

However, when looking at socio-economic status within the current study, the 2 mmHg difference across the tertiles may be more meaningful, considering the fact that the study sample consisted of a socio-economically homogenous group. Specifically, if the sample consisted of different groups of people/ communities (Aboriginals, single parents with economic challenges, certain ethnic groups etc), it may demonstrate clinically significant results, as shown in Rao & Apte, 2009 and Rao & Kanade, 2007.

Considering the covariates used in the different models, most variations of blood pressure measurements were explained by waist circumference, a measure of obesity. Currently, health promotional activities are facilitated to prevent and postpone high blood pressure or hypertension by modifying diet and engaging children in physical activities. Therefore, addressing obesity becomes more important than addressing a low LLHR in children and adolescents. From the results of the present study, participants with lower LLHR have the tendency to have higher blood pressure. While, 1% of variability in blood pressure is very small, the sample here reflects a relatively affluent population.

In addition to genetic predisposition, height as a biomarker of growth reflects the accumulation of positive and/or negative exposures during childhood. Leg length, as a marker of pre-pubertal growth, is sensitive to the environment in the first few years of life (Gunnel, Davey, & Frankel, 1998). This is because most of the increase in height during the pre-pubertal period is due to leg growth relative to overall height (Buckler, Kelnar, Stirling, & Saenger, 1998). As described by Isabella Leitch (1951), leg length is a more sensitive measurement than overall height in representing socioeconomic circumstances.

Understanding the link between LLHR and the impact of early life environmental exposures may be useful to explain the results of the present study. As socioeconomic status impacts environmental exposures, it can be inferred from the results of present study, that the relationship between LLHR and blood pressure is affected when the economic gap or economic inequality in the community is significant. Therefore, the difference seen in these results and the results from Rao & Apte, 2009 may be explained by the existing gap between the high and low socioeconomic status in developing countries as compared to the relatively smaller gap noted in developed countries. That is the difference between high and low socioeconomic status in a developed country like

Canada with the exception of severely disadvantaged groups such as those in northern Native communities and immigrant refugees, may be the reason for the demonstrated weaker relationship between LLHR and blood pressure among Canadian youth. In their studies in India, Rao and Apte (2009) and Rao and Kanade (2007) selected participants from low and high socioeconomic classes, which showed significant and strong relationships between blood pressure and LLHR. While these studies had their limitations, they suggest that the greater the socio-economic divide, the greater the likelihood of an LLHR effect on blood pressure.

Therefore, in developing countries, the relationship between LLHR and blood pressure in children and adolescents would be beneficial to identify those at risk for high blood pressure levels because the socioeconomic gradient is larger. Even in Canada, if this research was conducted in different populations with greater socioeconomic differences, it might have given more meaningful, clinically significant results.

The impact of socioeconomic status on blood pressure is reflected in several studies which looked at blood pressure, hypertension, and the complications of hypertension. Also, by understanding the link between leg length and height to early life environment, such as nutrition, illness and psychological disturbance, their importance to adult blood pressure can be emphasized. Intervention strategies can then be adopted linking these factors as well, to prevent or postpone developing hypertension as adults and thereby to reduce CVD risk.

Difference of Results Seen in Pulse Pressure

It is difficult to highlight the exact reason for the difference in the results for PP in this group of Canadian youth, but it is an area open to explore some possibilities. A difference in results for PP could be seen in the correlation of blood pressure measurements. There were strong positive correlations between SBP, DBP, and MAP, but PP had moderate positive correlation with SBP and weak negative correlations with DBP and MAP. These differences in the relationship of PP with the other three blood pressures may be an underlying reason for PP to show different nonsignificant results with LLHR in the present study.

As previously mentioned, PP is the difference between SBP and DBP, and it is the pulsatile component of blood pressure. PP reflects the stiffening of large arteries (Strandberg & Pitkala, 2003). A possible reason as to why there was no significant relationship observed between PP and LLHR in these children and adolescents, could be due to the fact that they did not have stiff large arteries. When reviewing the previous literature, studies involving PP were only carried out in adults. It was observed that even in adults, at different age ranges, PP behaved differently than SBP and DBP (Sesso et al., 2000). In a prospective study, which examined SBP, DBP, PP, and MAP and their ability to predict the risk of CVD, a study population of 11,150 male physicians were stratified into two groups: <=60 years and > 60 years. The median follow-up time was 10.8 years where the outcome was CVD events. In the younger group (<60 years), average SBP, DBP, and MAP strongly predicted CVD, and in the older group SBP and PP predicted CVD. Therefore, PP behaved differently in the younger than the older group showing a stronger association with CVD in the older age group. This is because SBP increases with age, while DBP increases up to about 60 years of age, and starts to decrease thereafter (Sesso et al., 2000). In children, we cannot understand the behaviour of PP as it has not been examined. There is no evidence of examining the similarities or differences in the four different blood pressure measurements among children either. However, there are differences in blood pressure measurements between children and adults, as blood pressure increases with age. In addition, there are differences in maturation and metabolism between children and adults. These could cause differences in the relationships between LLHR and blood pressure measurements in children and adults. This is the first study that looked at all four blood pressure measurements in children and adolescents.

In the existing literature, exploring the link between MAP and body measurements is less frequent. It was highlighted in an editorial (Schillaci, Pirro, & Mannarino, 2009) that MAP had similar predicting qualities as SBP and DBP in predicting CVD. However, more attention has been given to SBP in predicting CVD than DBP for several reasons, such as continuously increasing SBP with age (DBP only increases until about age 60 and then tends to stabilize), high prevalence rates of high SBP, poor control of SBP and more accuracy in measurement of SBP. It is important to consider MAP as well as it has similar predictive ability for CVD in adults (Schillaci et al., 2009); however, there is no evidence of using MAP in children and adolescents, with respect to predictive ability for CVD. The present study adds valuable information regarding LLHR, age, sex, WC, physical activity, family education, and parent history of high blood pressure with MAP.

Effects of Other Factors on the Relationship Between LLHR and Blood Pressure

It has been observed that blood pressure increases with age in children (Brotons et al., 1989; Landazuri et al., 2008; Williams, Hayman, Daniels, & Robinson, 2002; Shea et al., 1994; Sánchez et al., 1992). The present study showed that SBP, DBP, PP, and MAP increased between 9-14 years. Sánchez et al., 1992 examined children 1-18 years of age in a Spanish study looking at the relationship between blood pressure and age. It showed that SBP, on average, increased by 2mmHg with 1 year increment of age from 1-

13 years in males and females combined. The present study supports this finding as we found a 1.9mmHg increment for SBP for each 1-year increase in age.

Manatunga et al., (1993) did not identify a sex difference in blood pressure in children. Similarly, the present study did not find any significant difference in any of the blood pressure measurements between males and females. Sex did not have a significant effect in the regression models either. Rao and Apte (2009) and Rao and Kanade (2007) did their analyses on both sexes separately; however, they were not able to see any difference in the relationship of blood pressure and LLHR between males and females.

Overweight and/or obesity are positively associated with blood pressure (Lara et al., 2012; Papilia et al., 2012). In the present study, all blood pressure measurements increased with increasing WC. When moving from lowest to highest LLHR tertile, the percentages of overweight and obesity status statuses decreased (Table 21). These results confirmed the results shown by Liu et al., (2012) which demonstrated an inverse relationship with LLHR and overweight and obesity.

Farpour-Lambert and Shi (2009) showed that physical activity could reduce blood pressure in obese children. Results of the present study showed similar results establishing the benefits of reducing blood pressure (SBP, DBP, and MAP) with physical activity in the total sample. This indicated that when transitioning physical activity from often to sometimes and to never/rarely, blood pressure increased. However, subsample analysis showed opposite results, when parental education and parent history of hypertension were included in the models. Therefore, the findings for physical activity are inconsistent, identifying a need for further research.

Socio-economic status has been examined as a modifiable risk factor for cardiovascular diseases (Kaplan & Keil, 1993), represented by education, occupation and income. There is consistent evidence showing an inverse relationship with different indicators of socio-economic status and CVD, particularly, coronary artery disease (Kaplan & Keil, 1993). Lam, (2011), in an editorial commentary, highlighted that lower socio-economic status was associated with higher blood pressure and operated through mediators such as obesity and increased resting heart rate. Therefore, results of this present study need to be addressed in relation to socio-economic status, as LLHR reflects the socio-economic status in early childhood (Leitch, 1951) and relates to peri-adolescent blood pressure according to the results of current study. Among the measures of socioeconomic status, education is the most widely used measure to represent socio-economic status, as it is subjected to the least change, compared to the other two.

Shi, de Groh & Morrison, (2012), in the Canadian Health Measures Survey, displayed an inverse relationship between parental education and blood pressure in children. Those whose parents had postsecondary education had lower blood pressure levels compared to those with parents with no postsecondary education. In the present study, parent education was defined by six categories: from grade 11 or less, to graduate degree or professional training. Interesting results were seen for both DBP and MAP, in that an inverse relationship with parent education was found. However, SBP and PP were unable to show similar results. When moving up from one education level to the next, DBP decreased by 0.6mmHg and MAP decreased by 0.5 mmHg. However, it is unclear as to whether these small changes are due to the relatively affluent sample in our study. Specifically, the parent education level in our sample was higher than the Canadian general education level with the percentage holding a graduate degree or professional training at 20% in the HBEAT study compared to the Canadian average of 6.5% (Statistics, Canada, 2015).

According to the results of Shi et al., (2012), family history of hypertension showed a positive association with SBP and DBP among children and adolescents. The present study, however, did not show convincing results of the impact of parent history of hypertension. SBP and PP showed a positive, and DBP and MAP showed a negative association but none were significant. In Canada, the prevalence of hypertension was 24.4% among adults in 2005 (Tu et al., 2008), but in this study the prevalence of self-reported hypertension in either parent was 15.3%. One possible reason could be that the parent population in this study was younger than the general Canadian population and thus less likely to be diagnosed with hypertension. In the HBEAT study, parental age was asked in the questionnaire but somehow this information was missing in the dataset. As well, in terms of the percentages of immigrants, visible minorities and Aboriginals, the HBEAT dataset was much lower than the percentages reported for Ontario (Region of Niagara, 2016 "Health Statistics"). Also, there were significant differences in those who participated and those that who did not participate. Similarly, there were significant differences between the sample that completed the parent questionnaire and those that did not complete the parent questionnaires. Therefore, a non- representative sample from the HBEAT data compared to the Canadian general population could have led to a lower prevalence of hypertension among adults. Also, people who were diagnosed to have hypertension may have not have reported it in the questionnaire resulting in reporting bias.

In addition to the main objective of the present study, another important fact is highlighted regarding the prevalence of hypertension. The prevalence of hypertension in children and adolescents has been found to be highly variable in North America (Paradis et al., 2004; Salvedori et al., 2008; Shi et al., 2012). In the current study, the prevalence of hypertension was 1.2 %. This was similar to the prevalence seen by the Canadian Health Measures survey (Shi, de Groh & Morrison, 2012). Various methods have been used in measuring blood pressure with respect to resting time, interval between measurements, number of measurements, and method of calculation (Table 1). Even though there are clear guidelines as to how to take blood pressure measurements, the methods explained in different studies did not show that these guidelines were followed. Sorof and Daniel, (2002) pointed out that childhood high blood pressure was underdiagnosed due to various reasons in clinical practice. Blood pressure measurement errors can arise due to unavailability of the correct size cuff, etc. Therefore, the actual prevalence can be different from what is available from previous research.

Strengths of the Study

There were several strengths to this study. This was a community-based study which involved engagement from 10 schools. Involving the community is beneficial as it makes the findings more representative of the general population. It is better to understand the prevalence of hypertension and pre-hypertension in the community at large as well.

There were no exclusion criteria except that the participants who did not give consent were not included in the study. A considerably large sample size also can be considered as an advantage.

The accuracy of examination findings can be considered a strength. Understanding the variability of blood pressure, one method of improving accuracy was to take multiple measurements of blood pressure. There were six sequential measurements taken of blood pressure and three measurements of body measurements which improved the accuracy of the data. Whenever there was an erroneous reading in automated blood pressure measurement, manual blood pressure readings, using a Sphygmomanometer were performed to improve accuracy. Additionally, using an automated blood pressure monitor reduced the observer bias and digit preference, thereby minimized erroneous reading.

Also, this is the first study done in Canada to examine the link between LLHR and blood pressure in children. It was expected to open a new area of research with respect to finding another measure to relate to blood pressure. It could also direct research to use as a measure to predict other CVD risk.

Study Limitations

The present study results should be viewed with caution as there are some limitations. First, the participants who took part in the study may not represent the general population as most of students were Caucasian in origin. The third recognized limitation is the limited number of parent questionnaires that were available for analysis, only 67.6% returned the completed parent questionnaires. There was a significant difference in the LLHR and the percentages of males and females in the two groups of those who had the parent questionnaire and those who did not have a completed parent questionnaire. This could contribute to a non representative sample as well.

Another important limitation was associated with the sitting height measurement. Bogin and Varela-Silva (2010) had clear descriptions in defining the different anthropometric measurements. Leg length was defined as the length of the femur and tibia, the two main long bones in the leg. Leg length was calculated by subtracting sitting height from total height. The limitation of measuring sitting height in this study was that it could be subject to errors due to the presence of high gluteo-femoral fat, giving rise to a higher sitting height. Calculating leg length and LLHR, could have been underestimated in the obese children. This could impact the actual relationship of LLHR with blood pressure by exaggerating it or showing stronger relationship. However, controlling for obesity using WC may have eliminated the problem as gluteo-femoral fat correlates to hip circumference; hip circumference correlates to WC (correlation coefficient= 0.867; p <0.0001).

Adjusting for maturity is vital as adolescents participated in the current study. Age is one of the measures that may indicate maturity; however, age represents a wide variability in somatic and biological growth (Mirwald et al., 2002; Dorn, Dahl, Woodward, & Biro, 2006). Years from PHV is an indicator of maturity which uses anthropometric measurements. As the calculation of years from PHV involves height, sitting height and leg length, there was an overlap with LLHR, which can lead to problems of over adjusting. In the preliminary analysis, there was a weak positive correlation noted between LLHR and years from PHV (r=0.061, p<0.1181). When comparing age, and years from PHV, in the multiple regression models for SBP, DBP, and MAP age showed a much stronger association with LLHR with better significance levels than years from PHV. Therefore, age was the most appropriate factor to use to adjust for maturity with HBEAT data. However, as Mirwald, Baxter-Jones, Bailey, & Beunen (2002) highlighted, age is not the best indicator of maturity. This is considered a limitation.

Another limitation was in regards to the data of physical activity. Since physical activity data were collected using a self-reported questionnaire which is vulnerable to self-reporting bias, it was considered a systematic error. The question was a qualitative assessment regarding leisure activity performed in the last 7 days and, therefore, did not allow for clear demarcation of the level of physical activity for the students. However, regarding the Physical Activity Questionnaire, the reliability was highlighted by Sallis et al., (1993). They examined the validity and reliability of the self-reporting of physical activity and reported that validity and reliability are adequate for use of research in 5^{th} to 11^{th} graders.

Another important limitation is the lack of information on diet with respect to energy consumption. Gunnell et al., (1998 a) stated that diet in the early years of life is considered an important factor determining leg length and height measurements. In the HBEAT study, there were questionnaires asking about diet, dietary habits, and some specific foods, but it is difficult to come to a general conclusion regarding the child’s diet or energy consumption. Salt intake is valuable information when blood pressure is concerned, and information on salt intake is not available in the dataset.

Conclusions and Potential Applications

The burden of hypertension holds a huge socioeconomic impact on the society. The prevalence of hypertension in Canadian adults was as high as 24% (Robitaille et al., 2012), but interestingly childhood hypertension prevalence was less than 1% (Shi et al., 2012). Apart from genetic predisposition, it is believed that nutritional status and other environment factors in early life have an impact on growth and development. More specifically, exposure to adverse environmental factors can lead to shorter leg length and height and, also, LLHR. Previous studies on children and adolescents demonstrated an inverse relationship with LLHR and blood pressure.

The importance of this study lies in the potential tracking of blood pressure from childhood to adulthood. Those who have higher blood pressure as children are expected to have higher blood pressure as adults (Bao et al., 1995). If there is a relationship between LLHR and blood pressure among children and adolescents, it can be inferred that it can also predict adult blood pressure. This could prove helpful to address the burden of hypertension by early identification of those at risk and preventive measures to reduce future prevalence rates.

A relationship between LLHR and blood pressure in Canadian youth has been examined, which confirms the similar relationships observed in previous studies in other countries. The negative relationship between LLHR and blood pressure explained by the models in this study was small (R^2 = 0.06 to 0.18); it may, indeed, limit its application clinically. Measuring sitting height and height is feasible in clinical settings; thus, LLHR can be potentially used to identify children with higher levels of blood pressure. However, this can only be achieved if there is a strong relationship between LLHR and blood pressure. Also, whether those children identified by using LLHR will develop hypertension in the future needs more studies, especially longitudinal studies, to evaluate its predictive capability.

As such, the effect among children in highly disadvantaged socioeconomic groups at greater risk such as aboriginals, and new immigrants may demonstrate substantially lower LLHR. Therefore, LLHR, may possess a valuable piece of information, if further studies are conducted to examine LLHR in children from different socioeconomic classes.

As discussed earlier, good nutrition and other positive environmental factors during early years of life can be stressed in relation to growth, stature components, blood pressure, and thereby CVD.

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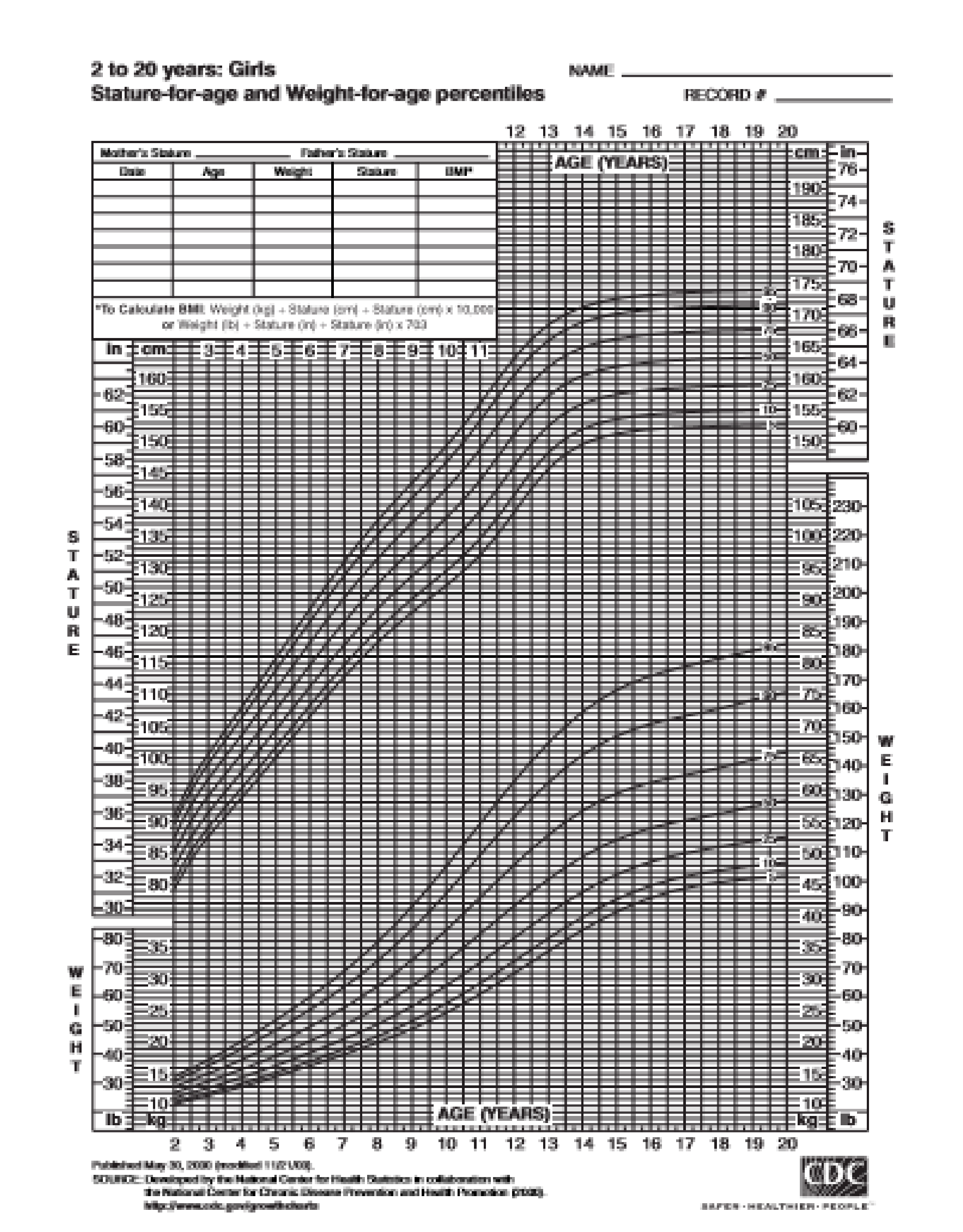
Appendix A

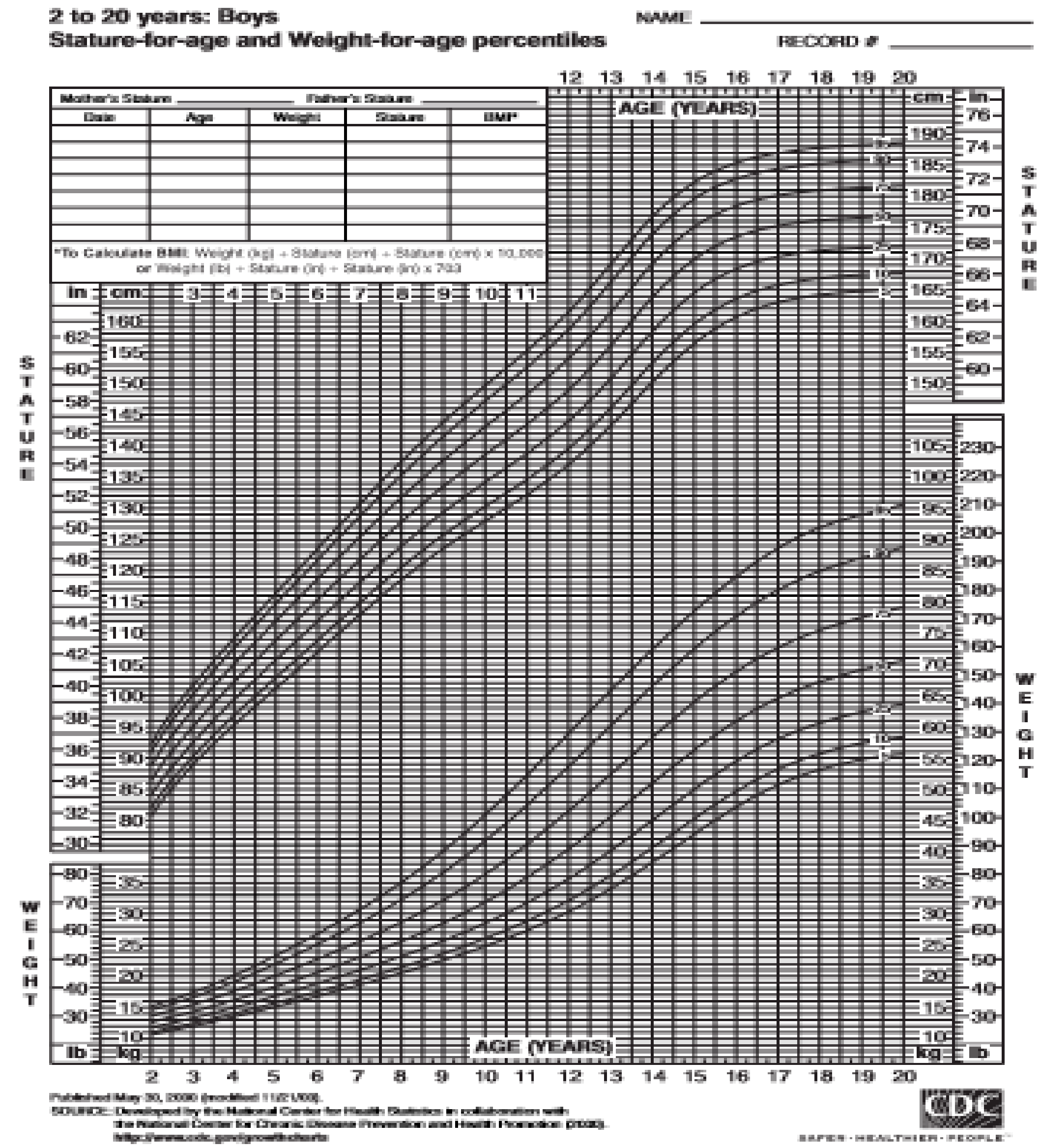
Conditions Under Which Children 3 Years Old Should Have BP Measured

History of prematurity, very low birth weight, or other neonatal complications requiring ICU
Congenital heart disease (repaired or non-repaired)
Recurrent urinary tract infections, hematuria, or proteinuria
Known renal disease or urologic malformations
Family history of congenital renal disease
Solid-organ transplant
Malignancy or bone marrow transplant
Treatment with drugs known to raise BP
Other systemic illnesses associated with hypertension (neurofibromatosis, tuberous sclerosis, etc)
Evidence of elevated intracranial pressure

Reprinted fromThe Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood
Pressure in Children and Adolescents*Pediatrics* 2004; 114; 555

Appendix B
Height Charts By Age For Girls and Boys (CDC Growth Chart)




2 to 20 years: Boys
Stature-for-age and Weight-for-age percentiles
NAME
RECORD #
Mother's Stature
Father's Stature
Date
Age
Weight
Stature
BMI*
*To Calculate BMI: Weight (kg) ÷ Stature (cm) ÷ Stature (cm) x 10,000
or Weight (lb) ÷ Stature (in) ÷ Stature (in) x 703
AGE (YEARS)
STATURE
WEIGHT
Published May 30, 2000 (modified 11/21/00).
SOURCE: Developed by the National Center for Health Statistics in collaboration with
the National Center for Chronic Disease Prevention and Health Promotion (2000).
http://www.cdc.gov/growthcharts
CDC
SAFER · HEALTHIER · PEOPLE

Appendix C

staple ballot to forms!

Dear Parents and Guardians:

Did you know that adults in Canada and the United States have a 90% chance of developing high blood pressure (also known as hypertension)? Did you also know that high blood pressure is one of the strongest predictors of heart disease? Some scientists even suggest that high blood pressure can start in childhood! Luckily, the Heart and Stroke Foundation of Ontario has provided us with a great opportunity to look at high blood pressure and heart health in children in the Niagara Region.

With the help of the Heart and Stroke Foundation, we have organized a research team to help gain a better understanding of high blood pressure among children. We already looked at students in the NCDSB in 2007/2008, but now we are asking for your help. We would like to invite you and your child to join our team and help us fight childhood high blood pressure – all it takes is a few blood pressure readings and some questions answered! Through our previous work, we have learned some of the factors that contribute to childhood high blood pressure, and now we would like to offer suggestions to families, schools, and communities to improve child heart health. By joining our efforts, this knowledge could help all children lead healthier lives and reduce their chance of having heart disease as adults.

Not only will you have the opportunity to learn your child's blood pressure and body mass, but you will gain a better understanding of their heart health, and have the chance to win prizes! **Please read the attached description for more information on our study.**

Please return the signed consent form to the teacher.

CONSENT FORM		
Student Name:	School:	
Parent/Guardian Name:	Teacher:	Grade:
Home Address:		
City/Town:	Postal Code:	Home Phone: ( ) -
☐ I **do give** permission for my child to participate in this stage of the Brock University HBeat study conducted by Dr. Terrance J. Wade.		
☐ I **do not give** permission for my child to participate in this stage of the Brock University HBeat study conducted by Dr. Terrance J. Wade.		
Signature of Parent/Guardian:	Date:	
Signature of Student:	Date:	

Additionally, all data collected may be used later to answer other research questions that may arise from this study. We would like your permission to keep the information that you and your child provided on file after this research study is over. All stored personal data will be kept strictly confidential and all information will be coded so that no one will be able to identify you or your child. At any time, you can ask to have your information removed and not included in any future projects by contacting Dr. Terrance J. Wade (905-688-5550 ext 4146). The investigators reserve the right to withdraw your child from the study if they believe that circumstances have arisen which warrant doing so.

☐ I **do give** permission to have my information and my child's information stored to use to answer future research questions after the HBeat study is over.	
☐ I **do not give** permission to have my information and my child's information stored to use to answer future research questions after the HBeat study is over.	
Signature of Parent/Guardian:	Date:
Signature of Student:	Date:

Please have your child return this form to their classroom teacher.

Please keep this information sheet for your records

What is HBEAT ?

Research with a ♥

HBeat stands for the Heart Behavioural and Environmental Assessment Team. The team examines how children's activities, surroundings, and actions affect their blood pressure. During our first Phase in 2007/2008, we examined all these factors in 1,900 students' lives, and have discovered some things that contribute to a rise in blood pressure. Now we are beginning our second Phase - from March 2010 to May 2010, we will test approximately 1,000 students in grades 5, 6 and 7. We will then follow up with these students again in 2011 when they are in grades 6, 7 and 8.

By saying yes, you and your child will be helping our study immensely. To begin, we will come to the school and measure your child's blood pressure, height, weight, hip circumference, and waist circumference, and give them a questionnaire about their activities. These measurements will take about 30 minutes of class time. We will also send home a questionnaire that you, the parent/guardian, will complete and return, and one for your child to complete and return. The parent form contains questions about yourself, your family and child(ren), your home, and your neighbourhood. The child form asks about their experiences, how they feel, and what they like to do and not do. In addition, one week later, we will randomly select about 15 students from each school to have a more detailed look at his/her heart and arteries (please see the attached information sheet for a more detailed outline of this further testing). This testing will be one-on-one, and will last approximately 30mins to 1hour. Parents are more than welcome to be present for any and all testing.

Following this initial testing, we will return to your school in one year (2011), and go through these procedures again.

In addition to the benefits of learning about your child's heart health, you and your child will have an opportunity to ***WIN* a family get-away to Great Wolf Lodge!** Every school involved will have their own draw, and one family from each school will win! This get-away includes a two-day water park pass, evening accommodation, and food vouchers for dinner and breakfast, for all immediate members of a family. Every student in each grade 5, 6, and 7 class has a chance to win! In addition, with each further portion of our study that you complete, you will receive an additional ballot into the draw! For example, a family will have one ballot for having a child in grade5, 6, or 7. The family will receive another ballot when they return the completed consent form (positive <u>or</u> negative consent!). The family will receive another ballot when the child participates in our blood pressure testing, another for returning the completed child questionnaire, and another for completing and returning the parent questionnaire! That's 5 ballots that you can possibly enter in the draw, and 5 chances of winning!!!

Your involvement and your child's involvement is completely voluntary and you both may withdraw from the study at any time. There is no obligation for you or your child to answer any or all of these questions, or to take part in any aspect of this project. If you do choose to withdraw, your prize ballots will remain in the draw.

** This study has been reviewed and approved by the Research Ethics Boards from both Brock University and the Niagara Catholic District School Board.*
**Any information about you and your child will only be seen by the researchers involved in this project. All private information will be kept strictly confidential and coded anonymously so that your name and your child's name are not associated with any answers to any questions. When the results of this project are presented, we will only use the combined data from all families so that no single child or family can be identified.*
**When the first stage of Phase 2 is complete, June 2010, we will send home your child's blood pressure results. We will do this again after the 2011 follow-up testing. When the entire Phase 2 is complete, we will provide your school with a report that you will be able to view. We also hope to publish these collective findings in peer-reviewed scientific journals. Please contact the researchers directly if you wish to personally obtain this information.*

We will be very grateful if you agree to take part in this important study. If you would like more information about the HBeat program, or if you have any questions, please contact Dr. Terrance Wade.
Thank you for your help!
<signature>
Dr. Terrance J. Wade

Please keep this information sheet for your records

What is HBEAT ?

Research with a ♥

HBeat stands for the Heart Behavioural and Environmental Assessment Team. The team examines how children's activities, surroundings, and actions affect their blood pressure. During our first Phase in 2007/2008, we examined all these factors in 1,900 students' lives, and have discovered some things that contribute to a rise in blood pressure. Now we are beginning our second Phase - from March 2010 to May 2010, we will test approximately 1,000 students in grades 5, 6 and 7. We will then follow up with these students again in 2011 when they are in grades 6, 7 and 8.

By saying yes, you and your child will be helping our study immensely. To begin, we will come to the school and measure your child's blood pressure, height, weight, hip circumference, and waist circumference, and give them a questionnaire about their activities. These measurements will take about 30 minutes of class time. We will also send home a questionnaire that you, the parent/guardian, will complete and return, and one for your child to complete and return. The parent form contains questions about yourself, your family and child(ren), your home, and your neighbourhood. The child form asks about their experiences, how they feel, and what they like to do and not do. In addition, one week later, we will randomly select about 15 students from each school to have a more detailed look at his/her heart and arteries (please see the attached information sheet for a more detailed outline of this further testing). This testing will be one-on-one, and will last approximately 30mins to 1hour. Parents are more than welcome to be present for any and all testing.

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Thank you for your help!
<signature>
Dr. Terrance J. Wade

Please keep this information sheet for your records

Detailed Testing

If your child is invited to participate in the second, more detailed testing one week after we test their blood pressure, below is an outline of the details. All measure will be taken in a private room by qualified individuals, and no risk is involved.

In addition to the blood pressure, weight, height, hip and waist measurements one week earlier, your child will have their skinfold thickness measured. Skinfold thickness will be assessed using a non-invasive method that measures skin thickness. The researcher lightly pinches the skin at the appropriate site to raise a double layer of skin and the underlying adipose tissue, but not the muscle. The calipers are then applied at right angles to the pinch and a reading is taken. Skinfold measures will be taken at two sites including the subscapular (lower shoulder blade) and triceps (back of the upper arm).

Your child will also lie down and have their heart rate monitored while their heart and right carotid artery (artery in the neck) are imaged using Doppler ultrasound (the same type of ultrasound seen in a hospital). Heart rate will be measured using sensors placed on the skin of your child's upper chest. These sensors are electrodes used to detect the electrical activity generated by the heart and do not transmit electrical signals into the body from the heart rate monitor. All carotid artery and heart ultrasound measures will be taken in a lying position. The carotid artery ultrasound will be performed using a small transducer to visualize the carotid artery. As well, carotid artery blood pressure will be taken at the same time using a thin pen-like device that is lightly pressed against the neck. Both the probe and pen like-device will be pressed against the neck on opposite sides. It is a non-invasive procedure. Second, the ultrasound of the heart will be performed with a small probe placed between your child's ribs on the left side of their chest. This procedure is also non-invasive and no risk is involved.

Parents are more than welcome to be present for testing.

Potential Risks and Discomforts
No risk is involved with these procedures. If an injury occurs at any time during the investigation, appropriate first aid/CPR will be administered and you will be advised to seek necessary medical help.

Benefits
A potential benefit for your child's participation in this project is the knowledge of their blood pressure, heart and artery assessment, as well as any underlying cardiovascular disease risk factors (take out??? Jose usually did this).

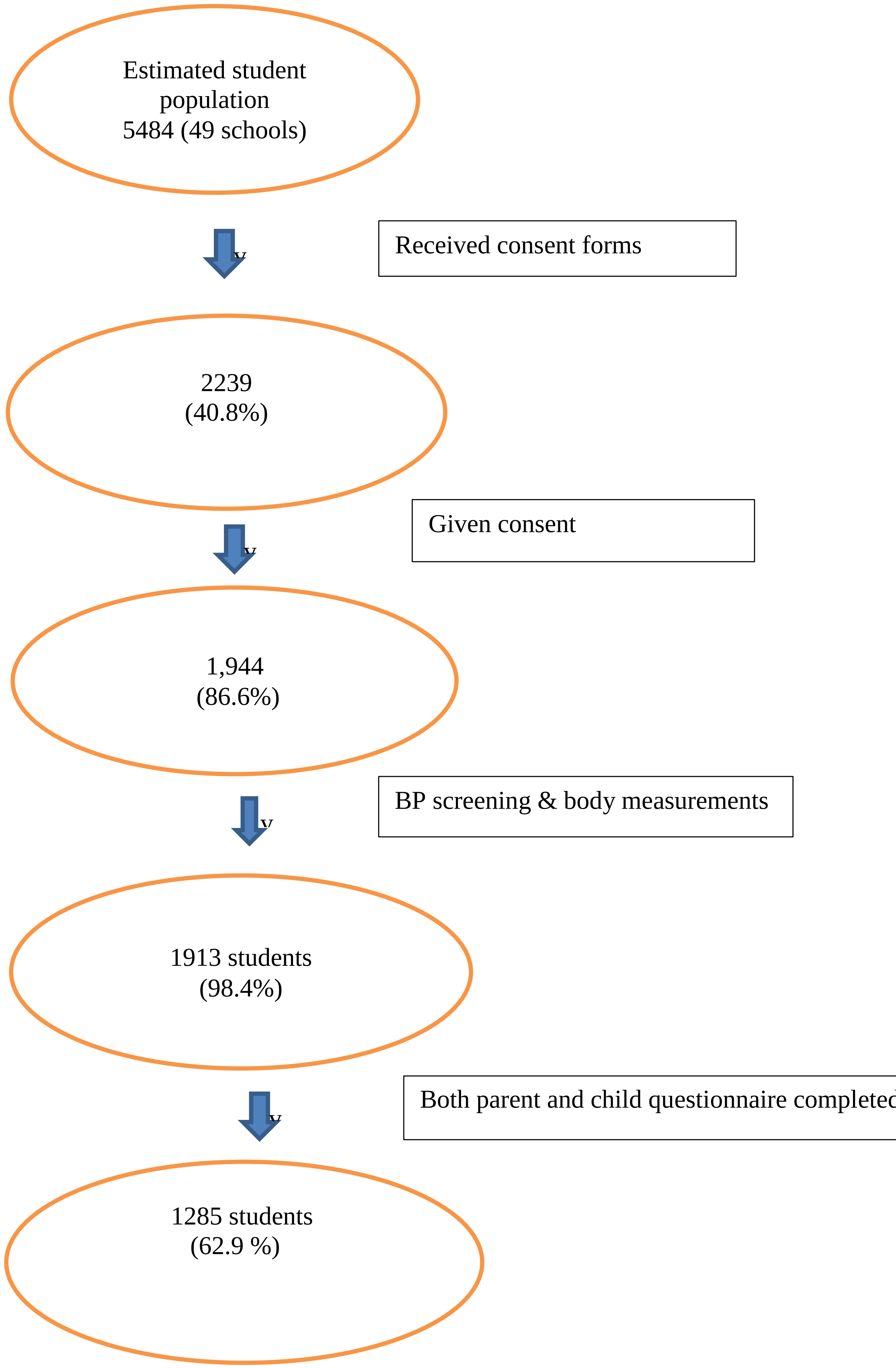
If you have any further questions regarding your rights as a research participant contact the Research Ethics Officer in the Office of Research Services at (905) 688-5550 x3035 or email at reb@brocku.ca.

Appendix D
Blood Pressure Percentile Charts

		Height		Systolic			Diastolic		
Sex	Age	Percentile	Index	Mean	p90	p95	Mean	p90	p95
F	10	all	1100	92.7	107.5	107.7	57.3	70.3	74.0
F	11	5th	1111	91.2	98.7	101.0	57.5	65.3	77.7
F	11	10th	1112	90.7	102.7	102.7	56.3	70.7	71.7
F	11	25th	1113	88.1	96.0	100.3	53.9	65.0	71.3
F	11	50th	1114	92.6	106.3	112.0	56.4	68.7	72.5
F	11	75th	1115	92.4	101.7	104.0	57.1	64.3	68.3
F	11	90th	1116	91.1	97.0	107.5	56.7	63.0	67.7
F	11	95th	1117	94.2	104.0	106.3	60.4	72.0	72.7
F	12	5th	1121	92.7	104.7	120.7	57.8	71.7	86.0
F	12	10th	1122	93.0	102.3	105.0	56.2	67.0	71.3
F	12	25th	1123	91.6	102.0	105.7	56.8	68.0	69.3
F	12	50th	1124	92.2	102.7	107.7	56.3	68.0	71.7
F	12	75th	1125	93.9	104.7	110.3	57.0	66.7	73.0
F	12	90th	1126	93.3	103.7	110.7	57.3	67.7	70.3
F	12	95th	1127	98.8	111.0	127.3	62.0	74.0	79.0
F	13	5th	1131	89.6	106.0	106.0	54.4	71.7	71.7
F	13	10th	1132	92.6	98.7	116.0	57.4	65.3	67.7
F	13	25th	1133	95.1	105.3	116.0	58.9	72.3	76.7
F	13	50th	1134	92.0	102.3	103.3	57.0	65.3	66.3
F	13	75th	1135	93.0	104.7	106.0	57.5	68.7	71.7
F	13	90th	1136	94.5	103.3	106.0	57.9	65.0	70.3
F	13	95th	1137	95.2	109.3	113.0	59.5	68.7	70.7
F	14	all	1140	94.3	106.0	107.5	59.3	67.3	68.7
M	10	all	2100	92.6	101.7	103.3	60.2	69.0	70.7
M	11	5th	2111	88.0	100.7	100.7	53.9	69.3	69.3
M	11	10th	2112	92.5	102.3	108.0	58.4	70.0	75.7
M	11	25th	2113	92.4	105.0	111.7	58.0	75.0	77.5
M	11	50th	2114	90.4	97.7	99.7	55.5	63.7	71.3
M	11	75th	2115	91.7	103.7	107.0	55.9	65.0	69.0
M	11	90th	2116	92.1	101.7	111.2	55.1	63.5	72.2
M	11	95th	2117	95.0	109.7	112.0	58.0	74.7	77.5
M	12	5th	2121	92.6	102.7	102.7	58.3	72.3	72.3
M	12	10th	2122	91.7	100.3	113.0	55.8	68.3	78.0
M	12	25th	2123	93.7	107.5	117.5	57.9	70.0	70.0
M	12	50th	2124	92.9	105.7	115.0	56.8	65.3	67.7
M	12	75th	2125	92.0	102.3	105.0	55.6	64.3	67.7
M	12	90th	2126	93.7	103.7	104.7	55.2	65.3	66.3
M	12	95th	2127	97.0	110.0	113.7	58.9	68.3	70.3
M	13	5th	2131	91.3	97.3	97.3	55.1	65.3	65.3
M	13	10th	2132	93.9	108.8	116.5	58.3	73.3	80.5
M	13	25th	2133	91.9	102.0	107.3	54.8	62.7	69.3
M	13	50th	2134	93.2	105.2	108.5	57.4	66.5	70.0
M	13	75th	2135	96.4	106.7	107.5	55.7	64.3	65.0
M	13	90th	2136	96.5	108.0	113.0	57.4	65.7	69.7
M	13	95th	2137	96.8	104.7	115.3	58.4	66.0	73.3
M	14	all	2140	93.5	104.0	105.7	56.5	62.0	65.3

Appendix E

Flow chart to visualize the HBEAT stage 1 sampling strategy



Appendix F

Student Questionnaire

HBEAT

Research with a

STUDENT DATA COLLECTION FORM

Student: School:

Grade: Teacher:

☐ Male ☐ Female

Date: ______/______/______ Time: ___:___ am/pm

(mm / dd / yy)

☐ Errors Occurred ☐ Manual

Questionnaire checked:______ (RA initial)

Reading:	2nd	3rd	4th	5th	6th	Manual Readings 1st	Manual Readings 2nd
Systolic							
Diastolic							
Heart Rate							

Recorded by:______ (RA initial)

Measurements:	1st	2nd	3rd
Height (cm)			
Weight (kg)			
Waist Girth (cm)			
Hip Girth (cm)			

Physical Measurements by: ______ (RA initial)

Subject ID Number: ____________________________________

Image Number: _____

Beat Number: _____

Diastole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Beat Number: _____

Diastole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Image Number: _____

Beat Number: _____

Diastole

Diameter 1: ___________

23 Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Beat Number: _____

Diastole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Image Number: _____

Beat Number: _____

Diastole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Beat Number: _____

Diastole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Systole

Diameter 1: ___________

Diameter 2: ___________

Diameter 3: ___________

Notes/Comments: ____________________________________

Subject ID Number: ____

Image Number: _____

Beat Number: _____

End-Diastole

IMT Average: _______________

IMT Maximum: _____________

IMT Mean: _________________

IMT PTS: ___________________

Beat Number: _____

End-Diastole

IMT Average: _____________

IMT Maximum: ___________

IMT Mean: ______________

IMT PTS: ________________

Image Number: _____

Beat Number: ______

End-Diastole

IMT Average: _______________

IMT Maximum: _____________

IMT Mean: _________________

IMT PTS: ___________________

Beat Number: _____

End-Diastole

IMT Average: _______________

IMT Maximum: _____________

IMT Mean: _________________

IMT PTS: ___________________

Image Number: _____

Beat Number: ______

End-Diastole

IMT Average: _______________

IMT Maximum: _____________

IMT Mean: _________________

IMT PTS: ___________________

Beat Number: _____

End-Diastole

IMT Average: _______________

IMT Maximum: _____________

IMT Mean: _________________

IMT PTS: ___________________

Notes/Comments:

Appendix G
Summary of Normal Distribution Assumption Check

A: Total sample

	Skewness	Kurtosis	A-D p value
Boys			
SBP	0.415	0.378	0.05
DBP	1.13	2.84	0.05
PP	-0.08	1.25	1.775
MAP	0.938	2.14	0.05
LLHR	1.33	6.36	0.05
Girls			
SBP	0.659	0.737	0.05
DBP	0.89	1.88	0.05
PP	0.214	0.385	1.821
MAP	0.885	1.73	0.05
LLHR	1.40	9.57	<0.05
Overall			
SBP	0.539	0.543	<0.05
DBP	1.024	2.45	<0.05
PP	0.055	0.871	0.0508
MAP	0.91	1.94	<0.05
LLHR	1.47	7.03	<0.05

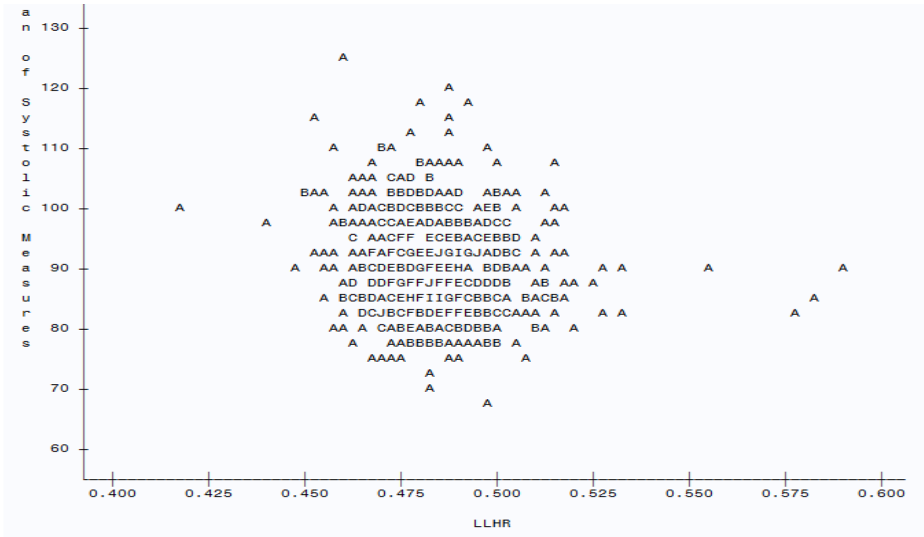
B: Sub sample

	Skewness	Kurtosis	A-D p value
SBP	0.91	3.40	<0.05
DBP	1.13	3.53	<0.05
PP	0.34	1.71	0.01
MAP	1.23	4.18	<0.05

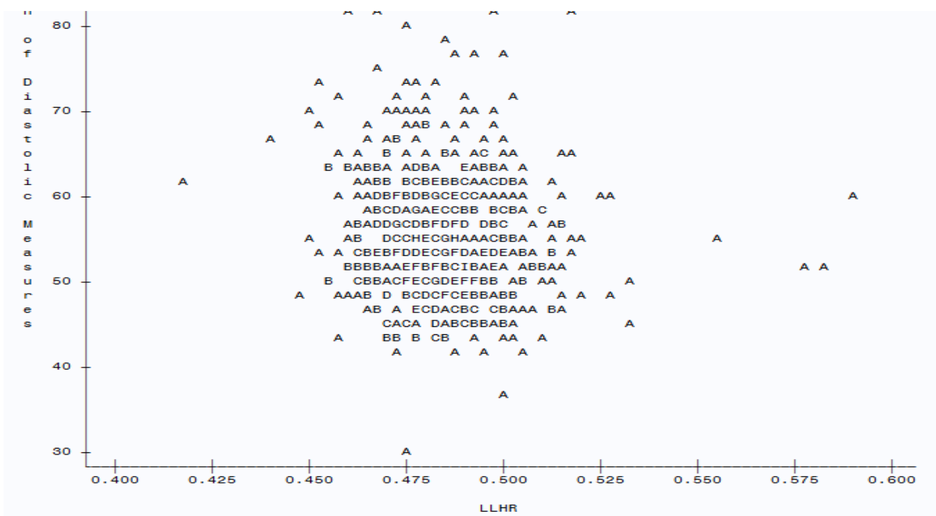
Appendix H

Scatter Plots Between Blood Pressure Measurements and LLHR

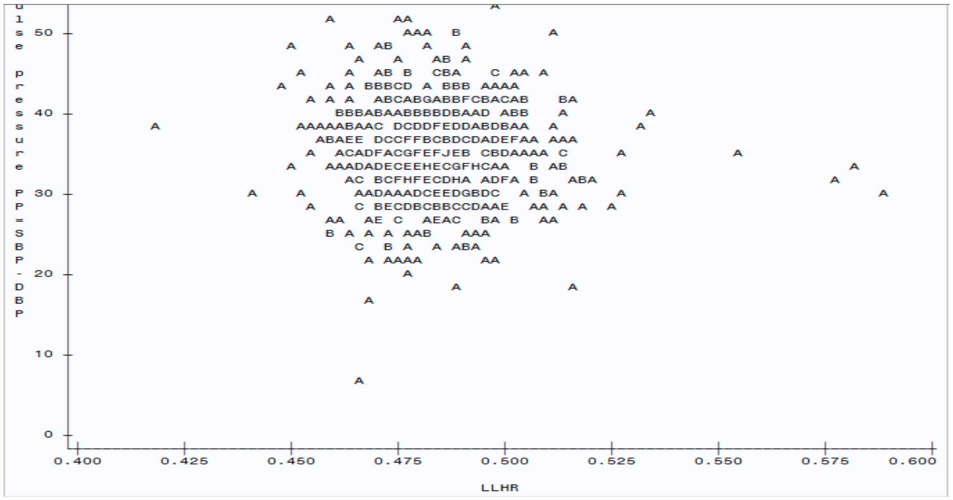
1.1Scatter plot of systolic blood pressure and LLHR



1.2 Scatter plot of diastolic blood pressure and LLHR



1.3 Scatter plot of Pulse pressure and LLHR



1.4 Scatter plot of Mean Arterial Pressure and LLHR